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(71)Applicant : ASML NETHERLANDS BV
(72)Inventor : FLAGELLO DONIS GEORGE
CUMMINGS KEVIN
STRAAIJER ALEXANDER
MARIE DIERICHS MARCEL MATHIJS
THEODORE

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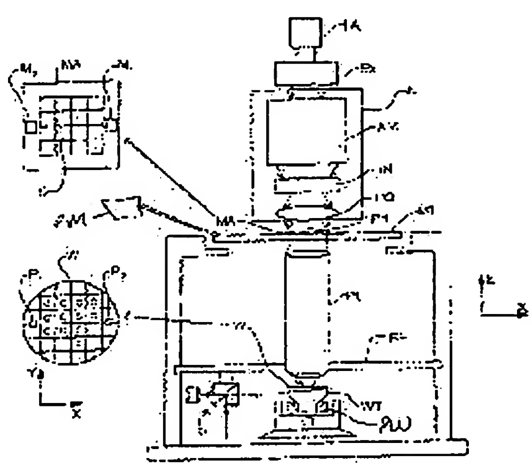
(54) FIXATION OF HIGH NUMERICAL APERTURE AND DYNAMIC RADIAL TRANSVERSE ELECTRIC POLARIZER

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a radial transverse electric polarizer comprising a first layer of material having a first refractive index, a second layer of material having a second refractive index and a plurality of elongated elements azimuthally and periodically spaced apart and disposed between the first layer and the second layer.
SOLUTION: A plurality of the elongated elements interact with electromagnetic waves of radiation to transmit transverse electric polarization of electromagnetic waves of radiation. The polarizer device may be used, for example, in a lithographic projection apparatus to increase imaging resolution. A device manufacturing method includes the polarizing of a radiation beam PB by means of a transverse electric polarization.



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CLAIMS

[Claim(s)]
[Claim 1]
It is a radial longitudinal direction electrical-and-electric-equipment polariscope device,
The 1st layer of an ingredient which has the 1st refractive index,
The 2nd layer of an ingredient which has the 2nd refractive index,
It **** periodically by the azimuth and has two or more long and slender elements arranged between said 1st layer and said 2nd layer,
The radial longitudinal direction electrical-and-electric-equipment polariscope device with which the long and slender element of said plurality interacts with the electromagnetic wave of a radiation, and penetrates longitudinal direction electrical-and-electric-equipment polarization of the electromagnetic wave of a radiation.
[Claim 2]
A radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 1 with said 1st refractive index equal to said 2nd refractive index.
[Claim 3]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 1 with which the long and slender element of said plurality forms two or more gaps.
[Claim 4]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 3 with which said gap includes air.
[Claim 5]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 3 with which said gap contains the ingredient which has the 3rd refractive index.
[Claim 6]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 1 with which said long and slender element has the 4th refractive index.
[Claim 7]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 1 by which said long and slender element is periodically ****(ed) with the period chosen so that the electromagnetic wave of said light might be polarized by longitudinal direction electrical-and-electric-equipment polarization.
[Claim 8]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 1 said whose electromagnetic radiation is ultraviolet rays.
[Claim 9]
It is a radial longitudinal direction electrical-and-electric-equipment polariscope device,
The substrate ingredient which has the 1st refractive index,
It is combined with said substrate ingredient, and has two or more long and slender elements by which orientation was carried out by the azimuth, and said long and slender element has the 2nd refractive index,
The radial longitudinal direction electrical-and-electric-equipment polariscope device which interacts with the electromagnetic radiation in which said two or more elements were ****(ed) periodically, and two or more gaps were formed therefore, which said radial longitudinal direction electric polarization machine device equipped with the 1st and 2nd polarization, reflects the radiation of the 1st polarization altogether mostly, and penetrates the radiation of the 2nd polarization altogether mostly.

[Claim 10]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 said whose 1st polarization is longitudinal direction MAG polarization and said whose 2nd polarization is longitudinal direction electrical-and-electric-equipment polarization.
[Claim 11]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 in which the long and slender element of said plurality is formed with an ingredient conductive on the wavelength in said electromagnetic radiation.
[Claim 12]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 11 with which said conductive ingredient is chosen from the group of aluminum, chromium, silver, and gold.
[Claim 13]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 in which said substrate ingredient is formed with an ingredient dielectric on the wavelength of said electromagnetic radiation.
[Claim 14]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 13 with which said dielectric ingredient is chosen from the group of a silicon dioxide, silicon oxide, silicon nitride, gallium arsenide, and its combination.
[Claim 15]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 with which said substrate ingredient is equipped with a dielectric ingredient.
[Claim 16]
Further,
It has the film of an absorptivity ingredient and the film of said absorptivity ingredient absorbs a radiation on the wavelength of said electromagnetic radiation,
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 by which the long and slender element of said plurality is covered by the film of said absorptivity ingredient.

[Claim 17]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 16 with which a part of reflective radiation of the 1st polarization which changed to the secondary radiation of the 2nd radiation is mostly absorbed by the film of said absorptivity ingredient.
[Claim 18]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 17 with which the radiation of the 2nd polarization is absorbed only for a critical mass by the film of said absorptivity ingredient.
[Claim 19]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 18 with which the film of said absorptivity ingredient cancels mostly the flare of the polarization in the equivalence radiation of the 2nd radiation.
[Claim 20]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 9 whose 2nd polarization is longitudinal direction electrical-and-electric-equipment polarization.
[Claim 21]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 16 with which the film of said absorptivity ingredient is chosen from the group of aluminum 2O3 and anodized aluminum.
[Claim 22]
It is lithography projection equipment,
The radiation system constituted so that the projection beam of a radiation might be offered,
It has the supporting structure constituted so that a patterning device might be supported, a patterning device is constituted so that pattern formation may be carried out to a projection beam according to a desired pattern, and it is a pan,
The substrate table constituted so that a substrate might be held,
The projection system constituted so that the beam which carried out pattern formation might be projected

on the target part of a substrate,
Lithography projection equipment equipped with the polariscope device built and arranged so that said radiation beam may be polarized in the direction of longitudinal direction electrical-and-electric-equipment polarization.

[Claim 23]

Said polariscope device
The 1st layer of an ingredient which has the 1st refractive index,
The 2nd layer of an ingredient which has the 2nd refractive index,
It **** periodically by the azimuth and has two or more long and slender elements arranged between said 1st layer and said 2nd layer,
Lithography projection equipment according to claim 22 with which the long and slender element of said plurality interacts with said radiation beam, and penetrates longitudinal direction electrical-and-electric-equipment polarization of said radiation beam.

[Claim 24]

Said polariscope device
The substrate ingredient which has the 1st refractive index,
It is combined with said substrate ingredient, and has two or more long and slender elements by which orientation was carried out by the azimuth, and said long and slender element has the 2nd refractive index,
Lithography projection equipment according to claim 22 which interacts with the radiation beam in which said two or more elements were ****(ed) periodically, and two or more gaps were formed therefore, which said radial longitudinal direction electrical-and-electric-equipment polariscope device equipped with the 1st and 2nd polarization, reflects the radiation of the 1st polarization altogether mostly, and penetrates the radiation of the 2nd polarization altogether mostly.

[Claim 25]

Said polariscope device is further equipped with the film of an absorptivity ingredient, and the film of said absorptivity ingredient absorbs a radiation on the wavelength of said electromagnetic radiation,
Lithography projection equipment according to claim 24 by which the long and slender element of said plurality is covered by the film of said absorptivity ingredient.

[Claim 26]

Lithography projection equipment according to claim 25 with which the film of said absorptivity ingredient is chosen so that the part of the reflective radiation of the 1st polarization which changed to the secondary radiation of the 2nd polarization may be mostly absorbed by the film of said absorptivity ingredient.

[Claim 27]

Lithography projection equipment according to claim 26 with which the radiation of the 2nd polarization is absorbed only for a critical mass by the film of said absorptivity ingredient.

[Claim 28]

Lithography projection equipment according to claim 27 with which the film of said absorptivity ingredient cancels the polarization flare of the transparency radiation of the 2nd polarization mostly.

[Claim 29]

Lithography projection equipment according to claim 25 whose 2nd polarization is longitudinal direction electrical-and-electric-equipment polarization.

[Claim 30]

Lithography projection equipment according to claim 25 with which the film of said absorptivity ingredient is chosen from the group of aluminum 2O3 and anodized aluminum.

[Claim 31]

Lithography projection equipment according to claim 22 which has the wavelength range of said radiation beam in an ultraviolet spectrum.

[Claim 32]

Lithography projection equipment according to claim 31 said whose wavelength range is for 365nm and 126nm.

[Claim 33]

Lithography projection equipment according to claim 31 which has said wavelength range in the extreme ultraviolet.

[Claim 34]

the electromagnetic radiation equipped with the 1st and 2nd polarization -- interacting -- the radiation of the 1st polarization -- almost -- all -- reflecting -- the radiation of the 2nd polarization -- almost -- all the radial

longitudinal direction electrical-and-electric-equipment polariscope devices to penetrate,
Each is equipped with the linearly polarized light machine plate of two or more sector forms where two or more parallel directions of the linearly polarized light are demarcated,
The polariscope device which the linearly polarized light machine plate of two or more of said sector forms is arranged by the azimuth, therefore the parallel direction of the linearly polarized light of said plurality rotates, and forms a radial polarization configuration.
[Claim 35]
The radial longitudinal direction electrical-and-electric-equipment polariscope device according to claim 34 built and arranged so that said radial longitudinal direction polariscope may rotate a right-angled axis as a core to the field demarcated with said radial longitudinal direction polariscope.
[Claim 36]
It is the device manufacture approach,
A substrate is partially projected for the radiation beam which carried out pattern formation on the target part of the layer of a wrap radiosensitivity ingredient at least,
An approach equipped with polarizing said radiation beam by longitudinal direction electrical-and-electric-equipment polarization.
[Claim 37]
The device manufactured by the approach according to claim 36.
[Claim 38]
It is a tangent polariscope device,
The cube beam splitter polariscope built and arranged so that it may polarize to the linearly polarized light in a part of incident light [at least],
It has a polarization plate equipped with two 1/2-wave plates,
Said polarization plate is arranged at the edge of said cube beam splitter polariscope, and polarizes said linearly polarized light to the 1st s-polarized light and the 2nd s-polarized light, therefore the wave vector of said 1st s-polarized light and the wave vector of said 2nd s-polarized light are a right-angled tangent polariscope device to mutual.
[Claim 39]
The tangent polariscope device according to claim 38 which uses said 1st s-polarized light, is horizontal, prints a line on a wafer, uses said 2nd s-polarized light, is perpendicular and prints a line on a wafer.
[Claim 40]
It is a polariscope device,
Polarization component,
It has the absorber arranged behind said polarization component,
The polariscope device with which said ingredient absorbs the radiation of said 2nd polarization altogether mostly including the ingredient which said polarization component interacts with the electromagnetic radiation equipped with the 1st and 2nd polarization, reflects the radiation of the 1st polarization altogether mostly, penetrates the radiation of the 2nd polarization altogether mostly, and said absorber absorbs on the wavelength of said electromagnetic radiation.
[Claim 41]
The polariscope device according to claim 40 which said polarization component is equipped with two or more long and slender elements by which orientation was carried out by the azimuth, and said two or more elements are ****(ed) periodically, and forms two or more gaps.
[Claim 42]
The polariscope device according to claim 41 whose long and slender element of said plurality is conductivity on the wavelength of electromagnetic radiation.
[Claim 43]
The polariscope device according to claim 40 said whose 1st polarization is longitudinal direction MAG polarization and said whose 2nd polarization is longitudinal direction electrical-and-electric-equipment polarization.
[Claim 44]
The polariscope device according to claim 40 by which said polarization component is equipped with two or more rings arranged on a concentric circle, and said ring is ****(ed) periodically.
[Claim 45]
The polariscope device according to claim 44 said whose 1st polarization is longitudinal direction electrical-and-electric-equipment polarization and said whose 2nd polarization is longitudinal direction MAG

polarization.
[Claim 46]
Reflective type lithography equipment which uses a modification machine device according to claim 40.
[Claim 47]
The modification machine device according to claim 40 with which said ingredient absorbed on said wavelength of electromagnetic radiation is chosen from the group of aluminum 2O3 and anodized aluminum.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention relates to an optical polariscope especially in general at the polariscope of the lithography of high numerical aperture.
[Background of the Invention]
[0002]
Lithography projection equipment is applicable to manufacture of an integrated circuit (IC). In such a case, a pattern formation means can generate the circuit pattern corresponding to each layer of IC, and can **** it into the target part (for example, it has one or more dies) on the substrate (silicon wafer) which covered this pattern with the layer of a radiosensitivity ingredient (resist). Generally, one wafer or substrate includes all the networks of the contiguity target part continuously irradiated through a projection system by 1 time per every **.
[0003]
If the vocabulary a "patterning device" is used on these specifications, it will be interpreted as pointing out the device which corresponds to the pattern which should be generated into the target part of a substrate, and can use the cross section which carried out pattern formation in order to give an incidence radiation beam by the wide sense. The vocabulary a "light valve" can also be used in this context. Generally, a pattern corresponds to the specific stratum functionale of devices generated into a target part, such as an integrated circuit or other devices.
[0004]
An example of such a patterning device is a mask. The concept of a mask is well known for lithography and includes mask types, such as a binary, a mutual phase shift and an attenuation phase shift, and still more various compound mask types. If such a mask is arranged to a radiation beam, the alternative transparency (in the case of a penetrable mask) or reflection (in the case of a reflexibility mask) of a radiation which collides with a mask according to the pattern on a mask will arise. In the case of a mask, the supporting structure is a mask table in general, it can hold in the location of a request of a mask of an incident radiation beam by this, and it is guaranteed that it can move to a beam according to a request.
[0005]
Another example of a patterning device is programmable Miller Alley. An example of such an array is a matrix addressable front face which has a viscoelasticity control layer and a reflexibility front face. The area where, as for the principle which becomes the origin of such equipment, for example, the reflexibility front face was addressed reflects incident light as refracted light, and the area which is not addressed is reflecting incident light as non-refracted light. If a suitable filter is used, the non-refracted light can be removed from a reflective beam, and it can leave only the refracted light. By this approach, pattern formation of the beam is carried out according to the addressing pattern of a matrix addressable front face.
[0006]
Minute Miller's matrix configuration can be used for programmable Miller Alley's alternative implementation gestalt, and each mirror can make it incline separately around an axis by giving the localized suitable electric field or using a piezo-electric starting means. Also in this case, matrix addressing is possible for Miller, therefore addressed Miller reflects a radiation beam in the different direction from Miller who is not addressed. By this approach, pattern formation of the reflective beam is carried out according to the addressing pattern of matrix addressable Miller. Required matrix addressing can be carried out using suitable electronic equipment. A patterning device can be equipped with one or more

programmable Miller Alley on the both sides of the situation mentioned above. The detailed information about Miller Alley who makes reference on these specifications is collectable by U.S. Pat. No. 5,296,891, U.S. Pat. No. 5,523,193, the international PCT patent application 98th / No. 38597, and the 98th / No. 33096. In the case of programmable Miller Alley, it may fix if needed or the supporting structure may be realized as the frame which can operate, or a table.

[0007]

Another example of a patterning device is a programmable LCD array. An example of such structure is given by U.S. Pat. No. 5,229,872. Like the above, it may fix if needed or the supporting structure in this case may be realized as the frame which can operate, or a table.

[0008]

In order to simplify, on these specifications, it points to especially the example in connection with a mask and a mask table after this in a specific part. However, please take into consideration the general principle which is examined in such a case in the context of a twist wide sense called a patterning device which was described above.

[0009]

With this equipment that uses pattern formation with the mask on a mask table, the machine of two different types is distinguishable. With the lithography projection equipment of one type, each target part is irradiated by making the whole mask pattern expose to a target part at once. Such equipment is usually called a wafer stepper. In the alternate device generally called scan step type equipment, parallel or reverse parallel is irradiated by carrying out the synchronous scan of the substrate table in this direction at each target part, scanning a mask pattern gradually in the reference direction (the "scan" direction) of arbitration under a projection beam. Generally, since a projection system has a scale factor M (in general <1), the rate V which scans a substrate table serves as a value which applies the rate which scans a mask table for a multiplier M. The detailed information about lithography equipment which is explained on these specifications can be seen by U.S. Pat. No. 6,046,792 included in this specification by reference.

[0010]

In the known manufacture process which uses lithography projection equipment, a pattern (for example, mask) is ****(ed) to the substrate partially covered in the layer of a radiosensitivity ingredient (resist) at least. In front of this **** step, various procedures, such as a priming, resist covering, and software BEKU, may be carried out to a substrate. A substrate can carry out other procedures, such as postexposure bake (PEB) of the picturized description, development, hard BEKU, and measurement/inspection, after exposure. IC etc. is used for this procedure of a series of as the base for carrying out pattern formation to each layer of a device. Such a layer that carried out pattern formation can carry out various processes, such as etching, an ion implantation (doping), metallization, oxidation, chemistry, and mechanical polish, next, and it has the intention of these all so that each layer may be finished. When several layers are required, the whole procedure or its deformation must be repeated for every new layer, and overlay (juxtaposition) of accumulated various layers is performed as correctly as possible. Therefore, a small reference mark is prepared in one or more locations of a wafer, therefore the origin of system of coordinates is demarcated on a wafer. When optics and an electron device are used combining the pointing device (it is called an "alignment system" below) of a substrate holder, whenever it makes the existing layer juxtapose a new layer, this mark can be rearranged, and it can be used as alignment criteria. Finally, an array-like device exists on a substrate (wafer). Next, with techniques, such as dicing or sewing, it dissociates from mutual, and it can equip with each device on a carrier, or these devices can be connected to a pin here. The further information about such a process is "Microchip Fabrication of for example, Peter van Zant work. : A Practical Guide to Semiconductor Processing It can gain from the work of the 3rd edition (McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4)."

[0011]

In order to simplify, a projection system is called this "a lens" or subsequent ones. However, please interpret this vocabulary in the thing and wide sense containing a projection system various type [, such as dioptric system, catoptric system, and cata-dioptric system,]. Orientation and since it fabricates or controls, a radiation system can also contain the component which operates by these design types of either, and can also call a projection radiation beam a "lens" by collective [such a component] below or independent. Furthermore, the type which has two or more substrate tables (and/or, two or more mask tables) is sufficient as lithography equipment. In the device of such "two or more stages", one or more tables are used for exposure, using it by making an additional table parallel, or carrying out a reserve step on one or more tables. Duplex stage lithography equipment is indicated by U.S. Pat. No. 5,969,441 and No. 6,262,796.

[0012]
If a new tool and a new approach are developed with lithography, the resolution of the **** device by which pattern formation is carried out on devices, such as IC, will be improved. It continues being improved and the tool and technique of optical lithography become even the resolution of less than 50nm depending on the case. This can be attained using abundant techniques, such as a lens (0.75 or more NAs) of comparatively high numerical aperture (NA), wavelength only with 157nm and a phase shift mask, and a different photoresist process from the former that illuminated and progressed.
[0013]
In order to make successful the manufacture process in resolution smaller than such wavelength, the capacity which prints a low modulation image, or the capacity to which an image modulation is made to increase to the level which takes out the yield of permissible lithography is used.
[0014]
Usually, industry used the Rayleigh criterion and has evaluated the function of the resolution of a process, and the depth of focus. Resolution and the depth of focus (DOF) are given by the bottom type.
Resolution = k1 (lambda/NA)
It reaches.
DOF=k2 (lambda/NA 2)
lambda is the wavelength of the lighting source and k1 and k2 are the constants of a specific lithography process here.
[0015]
Therefore, on specific wavelength, the depth of focus can be shortened as NA of the tool to be used is made high and resolution goes up. It is known well that DOF will be lost in high NA. However, as for the polarization target of a coherent system, NA is not inspected partially highly. A bottom type is followed.
[Equation 1]

$$I(r, Z_0) = \sum_i \int_s d\rho\, J(\rho_0) \,\Big|\, FT \Big\{ O(\rho-\rho_0)\, P_i(\rho)\, F_i(\rho,z)\, H(\rho,Z_0)$$

[0016]
Image I is the function of a location r with the film of arbitration, such as a photoresist, and is peculiar to the focal location Z0 of arbitration here. This formula is effective about all NA(s), and an image is the sum total of all the polarization conditions i. An integral is performed covering distribution of the source defined by J. The fourier term in a bracket shows the electric-field distribution in an exit pupil. The 4th term in a bracket is the object spectrums O, the polarization functions P, the functions F of a film, and the pupil functions H of a reticle pattern, respectively.
[0017]
According to this formula, high **** of NA is essentially related with a polarization condition and a diaphragm structure, and can change thoroughly the power and electric-field association which a photoresist film absorbs here. The power absorbed by the plane-of-incidence wave on a photoresist film is proportional to exposure required for the development of a film.
[0018]
"25th Annual International Symposium on Microlithography (SPIE) held in U.S. California Santa Clara on February 27, 2002 to March 3 Optical Lithography into the Millennium: Research of Donis G.Flagello announced with a title called Sensitivity to Aberrations and Vibrations and Polarization", and others Emitting greatly to a maximum of 25% of power change by NA with two high polarization (the longitudinal direction electrical-and-electric-equipment polarization TE and longitudinal direction MAG polarization TM) which intersects perpendicularly was shown. A **** system reduces this effectiveness including whenever [two or more incident angle]. However, a mutual phase shift mask (PSM) needs a small partial interference, and this may restrict the total of an include angle, therefore the same exposure change may be produced.
[0019]
A result is acquired from simulation and this shows that the limit-size difference in the condition of not

polarizing with the condition of having polarized completely is determined with numerical aperture NA. A result also shows that the line in a mutual phase shift mask (PSM) which crowded is the most important description, as for this, the configuration of a pupil generates interference of 2 beams fundamentally on wafer level, and this case is explained by by tending to make effectiveness of polarization into max. For example, (comparatively high), residual polarization must be restricted to 10% to choose the numerical aperture 0.85 and restrict a systematic limit-size CD error to less than 3%. Limit size CD is a minimum interval between possible 2 main tracks in the minimum width of face of a line, or manufacture of a device. A simulation result also shows that pupil restoration level and partial interference can make effectiveness of polarization small. This is shown by the effect of the small polarization to the device which used the conventional lighting.

[0020]

Therefore, since the **** technique which makes [many] the phase mask to be used and needs small interference level is used, the newer measurement technique of a lens may be needed. For example, lighting polarization of a lithography tool is specified very strictly as a result of the high polarization effectiveness of NA.

[0021]

157nm optical lithography is likely to be extended to less than 50nm downward enough depending on [nm / 70] the case, without changing the lighting source (laser) or a mask technique with the advent of the improvement technique (RET) in resolution called "liquid immersion." M.Switkes of the title "Immersion Lithography at 157 nm" announced by J.Vac.Sci.Technology B19 in 2001 11 / December (6) -- according to the paper of Massachusetts Institute of Technology (MIT) twisted in addition to this, a liquid immersion technique may negate the need for next-generation lithography (NGL), such as the extreme ultraviolet (EUV) and electronic projection lithography (EPL). A chemical and a resist are used for a liquid immersion technique, and it raises resolution. Immersion lithography can raise the resolution of the projection optics system which has the numerical aperture of the refractive index of immersion fluid by the highest. Numerical aperture NA is equal to the product of the refractive index n of a medium, and the sine of the half width of the cone of the light converged on the stippling image of a wafer (NA=n sintheta). Therefore, resolution can be raised, if a refractive index n is made to increase and NA is made to increase (resolution = see the formula of k1 (lambda/NA)). However, as mentioned above, when NA becomes high, the specification over lighting polarization of a lithography tool may become very severe. Therefore, the role which polarization plays in immersion lithography increases.

[Description of the Invention]

[Problem(s) to be Solved by the Invention]

[0022]

It is the mode of this invention to offer the radial longitudinal direction electrical-and-electric-equipment polariscope equipment containing the 1st layer of an ingredient which has the 1st refractive index, the 2nd layer of the ingredient which has the 2nd refractive index, and two or more long and slender elements which it ****(ed) periodically by the azimuth and have been arranged between the 1st layer and the 2nd layer. Two or more long and slender elements interact with the electromagnetic wave of a radiation, and penetrate longitudinal direction electrical-and-electric-equipment polarization of the electromagnetic wave of a radiation.

[Means for Solving the Problem]

[0023]

With one operation gestalt, the 1st refractive index is equal to the 2nd refractive index. With another operation gestalt, two or more long and slender elements form two or more gaps. These gaps can contain the ingredient which has air or the 3rd refractive index. With still more nearly another operation gestalt, a long and slender element is the period chosen so that the electromagnetic wave of the radiation of longitudinal direction electrical-and-electric-equipment polarization might be polarized, and is ****(ed) periodically.

[0024]

It is another mode of this invention to offer the radial longitudinal direction electrical-and-electric-equipment polariscope device containing two or more elements which were combined with the long and slender element which has the substrate ingredient which has the 1st refractive index, a substrate ingredient, and the 2nd refractive index and in which orientation was carried out by the azimuth long and slender. the electromagnetic radiation in which two or more elements are ****(ed) periodically, and two or more gaps are formed in, therefore a radial longitudinal direction electrical-and-electric-equipment polariscope device has the 1st and 2nd polarization -- interacting -- the radiation of the 1st polarization -- almost -- all --

reflecting -- the radiation of the 2nd polarization -- all are penetrated mostly.
[0025]
With the operation gestalt of this invention, the 1st polarization is longitudinal direction MAG polarization (TM), and the 2nd polarization is longitudinal direction electrical-and-electric-equipment (TE) polarization. Two or more long and slender elements can be formed with aluminum, chromium, silver, and gold. A substrate ingredient is good in Quartz (silicon dioxide), silicon oxide, silicon nitride, gallium arsenide, a dielectric material, and its combination.
[0026]
With another operation gestalt of this invention, a radial longitudinal direction electrical-and-electric-equipment polariscope contains the film of an absorptivity ingredient further by option. Two or more long and slender elements are covered with the film of the absorptivity ingredient absorbed on the wavelength of electromagnetic radiation. The film of an absorptivity ingredient is the part of the radiation which the 1st polarization reflected, and the part deformed into the secondary radiation of the 2nd polarization is chosen so that it may be mostly absorbed by the film of an absorptivity ingredient. By this approach, the film of an absorptivity ingredient can cancel mostly the polarization flare (fluctuation) of the transparency radiation of the 2nd polarization.
[0027]
Another mode of this invention is offering the polariscope device containing a polarization component and the absorber arranged behind a polarization component. A polarization component interacts with electromagnetic radiation including the 1st and 2nd polarization, reflects the radiation of the 1st polarization altogether mostly, and penetrates the radiation of the 2nd polarization altogether mostly. An absorber contains the ingredient absorbed on the wavelength of electromagnetic radiation. An ingredient absorbs the radiation of the 2nd polarization altogether mostly. A polariscope can be used with reflective type lithography equipment.
[0028]
With one operation gestalt, a polarization component contains two or more long and slender elements by which orientation was carried out by the azimuth. Two or more elements are ****(ed) periodically and form two or more gaps. Two or more long and slender elements may be conductivity on the wavelength of electromagnetic radiation. With an instantiation-operation gestalt, the 1st polarization is longitudinal direction MAG polarization, and the 2nd polarization is longitudinal direction electrical-and-electric-equipment polarization.
[0029]
With another operation gestalt, a polarization component contains two or more rings which have been arranged concentrically and ****(ed) periodically. With an instantiation-operation gestalt, the 1st polarization is longitudinal direction electrical-and-electric-equipment polarization, and the 2nd polarization is longitudinal direction MAG polarization.
[0030]
According to another mode of this invention, lithography projection equipment is offered. Equipment The radiation system built and arranged so that a projection radiation beam may be offered, The supporting structure built and arranged so that a patterning device may be supported is included. A patterning device The substrate table which is built and arranged so that pattern formation may be carried out to a projection beam according to a desired pattern, and holds a substrate further, The projection system built and arranged so that the beam which carried out pattern formation may be projected on the target part of a substrate, and the polariscope device built and arranged so that a radiation beam may be polarized in the longitudinal direction electrical-and-electric-equipment polarization direction are included.
[0031]
In the further mode of this invention, the device manufacture approach including projecting the radiation beam which carried out pattern formation of the substrate to the target part of the layer of a wrap radiosensitivity ingredient partially at least, and polarizing a radiation beam by longitudinal direction electrical-and-electric-equipment polarization is offered. Still more nearly another mode of this invention is offering the device manufactured using the approach mentioned above.
[0032]
Although especially the thing for which the equipment by this invention is used for manufacture of IC is mentioned on these specifications, such equipment should understand clearly that many other applications are possible. For example, you may use it for guidance and the detection pattern of an integrated optics system and magnetic domain memory, a liquid crystal display panel, the thin film magnetic head, etc. When

using the vocabulary a "reticle", a "wafer", or a "die" on these specifications about such an alternative application, the thing it should be considered that permutes it by the vocabulary respectively more common a "mask", a "substrate", and a "target part" is understood by this contractor.
[0033]
On these specifications, the vocabulary a "radiation" and a "beam" is used so that the electromagnetic radiation of all the types containing ultraviolet rays (wavelength is 365, 248, 193, 157, or 126nm) and EUV (it has the wavelength of the extreme ultraviolet, for example, the range which is 5-20nm), and a particle beam still like an ion beam or an electron beam may be included.
[0034]
the above of this invention, and the other purposes -- current [of this invention] -- by taking into consideration detailed explanation of the following related with a desirable instantiation-operation gestalt in connection with an accompanying drawing, he becomes still clearer and I am understood still more easily.
[Best Mode of Carrying Out the Invention]
[0035]
Some techniques have been used in order to generate polarization. In order to polarize in a natural configuration, i.e., unpolarized light, there are four techniques fundamentally. One technique is based on a birefringence or a biaxial ingredient. The 2nd technique is based on use of dichroic ingredients, such as a "Polaroid." The 3rd technique uses a thin film technology and uses the brewster effectiveness. The 4th technique is based on a wire grid or a conductive grid.
[0036]
Polarizing light using a birefringence ingredient is known for production of a birefringence polariscope. A birefringence polariscope can be created also from many crystals and specific extension polymers. A birefringence ingredient is an ingredient which has a different refractive index from another direction in an one direction. Extent of the difference of the refractive index in a 2-way changes according to the wavelength of light. The difference of a refractive index is used and the beam of the one linearly polarized light is separated with another it. Use of a birefringence polariscope needs the light by which was characterized by the engine performance depending on inefficiency and wavelength, and the collimation was carried out to altitude. Generally from these reasons, a birefringence polariscope is not used in an optical projection system.
[0037]
A dichroic polariscope is a polariscope designed so that one polarization might be absorbed and another side might be penetrated. The dichroic polariscope most generally used is extended so that orientation of the molecule may be carried out, and it consists of polymer sheets processed with iodine and/or other ingredients, or a chemical so that a molecule may absorb polarization of an one direction. An extension polymer polariscope absorbs at least 15% of all the reinforcement of one polarization, and the transmitted polarization. An extension polymer polariscope deteriorates with time amount. It is because it becomes [whether an ingredient becomes yellow by light inducing the chemical change of a polymer ingredient consequently, and]. The dichroic polariscope is sensitive to heat and other environmental change.
[0038]
The polariscope device which made the extension polymer sheet the birefringence in these ten years was developed. This extension sheet reflects one polarization and passes another side. One problem of this polariscope technique is a low extinction coefficient called about 15. Although it is useful depending on an application, this extinction coefficient is not enough for a **** application without a secondary polariscope. This type of polariscope is afflicted also from the environmental problem mentioned above.
[0039]
The beam of light which carries out incidence of the thin film polariscope technique to the front face of ingredients, such as glass and plastics, by whenever [Brewster's angle] (about 45 degrees) is divided into two polarization beams, penetrates one side, and another side uses the brewster effectiveness to reflect. However, a thin film polariscope technique restricts the include-angle range of beam-of-light incidence. The permission include-angle range is restricted very narrowly by most devices with abundance. A thin film polariscope technique is afflicted by the dependency of wavelength for the dependency of whenever [over the wavelength of incident light / Brewster's angle].
[0040]
The one where a beam is brighter is always desirable in the image projection system which explores application of a polarization beam of light. The brightness of a polarization beam is determined by many elements and one of the elements is the light source itself. Another element of the system which uses a

polariscope is a light-receiving angle. A light-receiving angle is narrow or the system which uses a light-receiving angle with the restricted large polariscope cannot collect much light from the emission light source. The polariscope with a large light-receiving angle can give versatility to the design of a projection optics system. This is because it is not necessary to arrange and carry out orientation of the polariscope by narrow light-receiving angle within the limits to the light source.

[0041]

Another desirable description of a polariscope is separating one component of polarization from other components effectively. This is called an extinction coefficient and is the ratio of the amount of the light of the polarization component of the request to the amount of the light of the polarization component which is not desirable. It is that a degree of freedom is in arrangement of the polariscope of an optical projection system, without reducing the effectiveness of a polariscope with other desirable descriptions, or preparing constraint of an addition to systems, such as orientation of a beam, in them.

[0042]

A conductive grid or a wire grid is used for another polarization technique. A wire grid polariscope is the assembly of the flat surface where the parallel electric conductor with die length far longer than width of face became at equal intervals, and spacing between electric conduction elements is shorter than the wavelength for highest frequency Mitsunari of an incident ray. This technique has succeeded in use for years to a radio frequency field and the infrared field of a spectrum. Reflecting the wave (S polarization) of polarization parallel to a conductor, the wave (P polarization) of rectangular polarization penetrates a grid. A wire grid polariscope is mainly used in the field of a radar, microwave, and infrared radiation.

[0043]

The wire grid polariscope technique was not used for comparatively short wavelength except for some cases in the visible wavelength range. For example, the wire grid polariscope of a visible spectrum is indicated in U.S. Pat. No. 6,288,840. A wire grid polariscope is embedded into ingredients, such as glass, and this is inserted between the 1st layer of an ingredient, and the 2nd layer including the element of the shape of a long and slender array ****(ed) by being parallel. A long and slender element forms two or more gaps between elements, and this offers a refractive index smaller than the refractive index of the 1st layer. The array of an element interacts with the electromagnetic wave of a visible spectrum, reflects a great portion of light of the 1st polarization, and it is constituted so that a great portion of light of the 2nd polarization may be penetrated. An element has the period of less than 0.3 microns, and width of face of less than 0.15 microns.

[0044]

Another case where a wire grid polariscope is used for polarization of a visible spectrum is indicated by U.S. Pat. No. 5,383,053. A wire grid polariscope is used for virtual image display, and reflection and transparency effectiveness are improved from the conventional beam splitter. A wire grid polariscope is used as a beam division element of polarization-on axis virtual image display. The extinction coefficient of a grid polariscope did not become a problem for this application. For this application, an image already polarizes and it is because only the comparatively high effectiveness of reflection and transparency was a problem.

[0045]

Lopez and others are the papers announced by Optical Letters (Vol.23, No.20, pp.1627-1629), and explain use of the surface relief grid polarization similar to a wire grid technique. Lopez and others explain use of the grid polarization in the visible spectrum (output of 632.8nm helium-Ne laser) as the quarter-wave length plate polariscope (the phase delay pi / 2) in vertical incidence, and a polarization beam splitter (PBS) of whenever [40-degree angle-of-incidence]. Periods are [0.3 microns and the duty cycle of a polariscope] 50% of 1-dimensional surface relief grids. The grid ingredient is inserted into Si3N4 (refractive index 2.20) two-layer in a melting Quartz substrate top in SiO2 (refractive index 1.457) of a monolayer.

[0046]

However, use is not suggested to the wire grid polariscope technique in the ultraviolet-rays wavelength range, i.e., the range shorter than the visible-ray minimum wavelength of 400nm. As mentioned above, by development of the polariscope of ultraviolet rays, the resolution of a lithography projection system can be raised and the resolution of the lithography projection system which has high NA can be especially raised like [in the case of being an immersion lithography system].

[0047]

Ferstl and others are the papers announced by SPIE (Vol.3879, Sept.1999, pp.138-146), and are indicating use of a "RF" grid as a polarization element. The binary grid with device size smaller than the lighting

wavelength which is 650nm is manufactured by the fine structure technique within Quartz glass combining continuous reactive ion etching in direct electron beam writing. At the polarization beam splitter, about 80% of diffraction efficiency was acquired by the 1st [-] order of longitudinal direction electrical-and-electric-equipment TE polarization, and 90% of diffraction efficiency was acquired by zero-order [of longitudinal direction MAG TM polarization].

[0048]

The polarization condition of a wave is defined by two parameters theta and phi, theta defines the relative magnitude for TE and TM wave Naganari here, and phi defines the relative phase. An incident wave can be expressed with the pair of the following formulas.

ATE=costheta and ATM=ejphisintheta

[0049]

Therefore, in the case of phi= 0, the linearly polarized light of the wave is carried out at an include angle theta. In the case of theta=pi / 4, and phi=**pi/2, the circular polarization of light is acquired. TE polarization is expressed with theta= 0. A TM wave is expressed with theta=pi/2. TE and TM polarization are fundamental polarization components.

[0050]

Before progressing to the detail about a polarization system and a polarizing lens, it is wise to be the context of the application, that is, to consider polarization in the context of a lithography tool and an approach.

[0051]

Drawing 1 shows roughly the lithography projection equipment 1 by the operation gestalt of this invention. The radiation system Ex built and arranged so that equipment 1 may supply the projection beam PB of a radiation, In the case of this specification, this is equipped with the radiation source LA including IL. Further In order to hold Masks MA (reticle etc.), a mask holder is formed, and the 1st object table (mask table) MT connected to the 1st positioning device PM for positioning a mask correctly to the projection system PL is included. The 2nd object table WT connected to the 2nd positioning device PW which forms the substrate holder holding Substrates W (silicon wafer which carried out resist covering), and positions a substrate correctly to the projection system PL (substrate table). It is constituted and the projection systems ("lens") (Mirror Group Newspapers etc.) PL are arranged so that the exposure part of Mask MA may be ****(ed) into the target part C of Substrate W (for example, it has one or more dies).

[0052]

As this specification shows, equipment is a penetrable type (that is, it has a penetrable mask). However, a refraction type (it has a refractility mask) may be used generally, for example. Or the patterning device of another kind like programmable Miller Alley of a type which was mentioned above may be used for equipment.

[0053]

Sources LA (plasma source generated by discharge or laser) generate a radiation beam. This beam is supplied to lighting system (lighting system) IL, after crossing adjustment devices, such as direct or the beam dilator Ex. A lighting system IL may be equipped with an accommodation means AM to set up the outer diameter and/or bore range (for it to be called Exterior sigma and Interior sigma generally, respectively) of intensity distribution of a beam. Moreover, this is generally equipped with other components with various accumulation machines IN, Capacitors CO, etc. The beam PB which collides with Mask MA by this approach has desired intensity distribution in that cross section.

[0054]

About drawing 1 , although Source LA is good within housing of lithography (Source LA for example, it is often when it is mercury-vapor lamp like) projection equipment, it may be separated from lithography projection equipment, and the radiation beam which this generates may be drawn in equipment (with for example, suitable orientation Miller's assistance). in the case of the latter, it is alike occasionally, it is carried out, and Source LA is an excimer laser. This invention includes both these scenarios.

[0055]

Beam PB intersects after that the mask MA held on the mask table MT. If Mask MA is crossed, Beam PB will pass Lens PL and this will converge Beam PB on the target part C of Substrate W. It can be made to move correctly so that the substrate table WT may be positioned into the target part C from which the way of Beam PB differs with the help of the 2nd positioning device PW and the interferometer measurement means IF. After similarly using the 1st positioning device PM, for example, taking out Mask MA from a mask library mechanically, Mask MA can be correctly positioned to the way of Beam PB during a scan. Generally, actuation of the object tables MT and WT is realized by drawing 1 with the help of the long

stroke module (coarse positioning) which is not illustrated clearly and a short stroke module (detailed positioning). However, what is necessary is just to fix to this as the mask (scan step type equipment is difference) table MT is connected to a short stroke actuator in the case of a wafer stepper. Mask MA and Substrate W can be positioned using the mask alignment marks M1 and M2 and the substrate alignment marks P1 and P2.

[0056]

The equipment of illustration can be used in the two different modes. In step mode, the mask table MT is fundamentally maintained by the quiescent state, is 1 time, that is, projects the whole mask image on the target part C with one a "flash plate." Next, the substrate table WT is shifted in X and/or the direction of Y so that a target part C which is different with Beam PB can be irradiated.

[0057]

In scan mode, although the same scenario is fundamentally applied, the given target part C is not exposed with one a "flash plate." The mask table MT can operate at a rate v in the given direction "the so-called scanning direction of Y", for example, the direction, therefore makes the projection beam PB scan a mask image instead. The substrate table WT moves to this direction or hard flow by rate V=Mv at coincidence at it and coincidence, and M is the scale factor (usually M= 1/4 or 1/5) of Lens PL here. The comparatively large target part C can be exposed without compromising resolution on this approach.

[0058]

TE polariscope is not used for the lens used for current and projection lithography. This has the linearly polarized light or the circular polarization of light. The polarization condition of the lithography tool currently used before this invention is a straight line, a round shape, or unpolarized light. The artificer judged that TM polarization needed to be controlled in the direction of a complete aircraft style, in order that resolution might be improved and NA might enable it to improve **** in NA with larger, high immersion lithography than 1 etc. Otherwise, loss of contrast will become excessive, so that it is enough to destroy **** which can be performed.

[0059]

in order to cancel TM polarization and to use only TE polarization by lithography projection, an artificer needs to lose TM polarization component alternatively, if a radial polariscope is used for a circle symmetrical lens -- ****** was discovered. Manufacture of a radial polariscope is the same as that of it of the wire grid technique mentioned above. This is attained by manufacture of radial period metal wires, such as chromium embedded on a lens element or in the lens element or silver, a dielectric, or a multilayer.

[0060]

Drawing 2 A is the schematic drawing of the operation gestalt of the radial polariscope by this invention. The radial polariscope 20 has the periodic lattice 22 arranged by the pattern of the symmetry radial. The period of a grid can be chosen according to the wavelength of the specific radiation to be used, and the parameter of other requests. With this operation gestalt, a grid adheres on a substrate 24, and this is good with glass or other ingredients. A grid 22 is good with the ingredient of arbitration conductive on the wavelength of aluminum, chromium, silver, gold, or an electromagnetic radiation beam. A grid can also create inserting SiO2 of a dielectric or a monolayer by Si3N4 two-layer in a melting Quartz substrate top etc. in the combination of multilayer structure. A grid 22 may be etched after the pattern imprinted to the substrate of GaAs using an electron beam.

[0061]

Drawing 2 B is the enlarged drawing of the grid 22 in the area 26 of a polariscope 20. As drawing 2 B shows, the grid 22 is combined so that the polarization effectiveness can change smoothly, in order to maintain the homogeneity of TE polarization reinforcement along with the diameter of a polariscope.

[0062]

Although the polariscope 22 is illustrated by drawing 2 A so that it may have a disk form, polygons, such as a rectangle and a hexagon, are sufficient as a polariscope 20.

[0063]

Drawing 3 is the expansion side elevation of another operation gestalt of a radial polariscope. the ingredient of the ingredient with which the radial polariscope 30 has the 1st refractive index which has the 1st layer of 32 and the 2nd refractive index -- 34 [layer / 2nd] is included. Two or more long and slender elements 36 (or grid) periodically ****(ed) by the azimuth are arranged between 34 the 2nd layer with 32 the 1st layer. Interact with the electromagnetic wave of light or a radiation, and longitudinal direction electrical-and-electric-equipment TE polarization is made to penetrate, and two or more long and slender elements 36 reflect, or absorb TM polarization. Two or more long and slender elements 36 can be created for example,

with diacid-ized silicon etc., and the 2nd layer can be created with the 1st and/or the ingredient of arbitration with which 32 and/or 34 are equipped with Quartz, silicon, a dioxide, silicon nitride, gallium arsenide, etc., or the ingredient which becomes a dielectric on the wavelength of an electromagnetic radiation beam. Like a former operation gestalt, spacing or the period between the long and slender elements 36 can be doubled with expected use of a polariscope, i.e., specific wavelength, and can be chosen according to other parameters of a lithography system.

[0064]

Similarly, although the polariscope 30 is illustrated by drawing 3 so that it may have a part of disk form and a disk form, a polariscope 30 may have a part of polygons, such as a rectangle and a hexagon, and a polygon.

[0065]

The polarization condition changes, therefore, as for the light which collides with polariscopes 20 and 30 by whenever [incident angle / of a right angle] mostly, the output of a transparency polarization condition is right-angled in the direction of the gridlines 22 and 36 of polariscopes 20 and 30.

[0066]

Drawing 4 is the vector diagram 40 which has the preferential polarization direction 41 and preferential output from the TE polariscope 20. Since the demand to TE polarization by the system with NA high on the edge of a pupil becomes large, an error and a defect can be enlarged toward the core of a polariscope. The coherent light illuminated through the line (line of a reticle image) of high density generates the 3rd diffraction. 42 becomes the location of the zero-order diffraction of a beam of light, and becomes the location of the primary [+] each diffraction and -primary diffraction of a vertical line in 44 and 45. 46 and 47 become the location of the primary [+] each diffraction and -primary diffraction of a horizontal line. + 1 and the 1st [-] order are interference which generates a trough and a peak for the lighting which reaches a wafer. When using TE polarization, in both a vertical line and a horizontal line, an interference pattern is generated, high contrast is followed and the good resolution of a line is produced.

[0067]

In the case of the linearly polarized light, only one side becomes a clear interference pattern by high contrast among a vertical line or a horizontal line. The perpendicular or horizontal line of another side does not polarize correctly, but contrast becomes low, without forming an interference pattern. If the image of high contrast and low contrast is combined, a result will be averaged and the visibility or resolution of **** will fall by the whole pattern. In order to avoid the component which interference with a wafer is lost or becomes minute, the artificer used the radial TE polariscope which an interference pattern can produce in the direction of an azimuth of the arbitration of a lens. This is not applied to the circular polarization of light. Although each component is the combination of two straight-line rectangular cross polarization, and it rotates all over space, it is because it is thought that it is in the condition fixed as a function of a location. Therefore, if the circular polarization of light is used, an interference line does not arise, consequently it is not suitable for high resolution **** of a lithography system. It is because the circular polarization of light changes to the linearly polarized light in respect of a wafer and this fault is mentioned above within this paragraph.

[0068]

With an immersion lithography system, i.e., a lithography system with high NA, since sufficient resolution to **** the line of high density is gained, use of TE polariscope may be needed. Drawing 5 shows the process window of the unpolarized light immersion lithography system of Example 1 for a comparison which **** the line of 50nm high density. The operating wavelength of this example is 193nm. The refractive index of the immersion fluid to be used is water (NA=1.437) of 1.437. The numerical aperture NA of air and equivalence is 1.29. The resist used in this example is PAR710 which Sumitomo Corp. of Japan created, and is put on the substrate which matched. Lighting is annular [of sigma=0.9/0.7]. Drawing 5 is a plot with the exposure latitude of Example 1 for a comparison, and the depth of focus. Exposure latitude [in / in this plot / the depth of focus of 0.00] shows that it is about 5.6%, and this is unusable level. Exposure latitude falls further and it becomes impossible for NA to use unpolarized light light for a high lithography system in other depth of focuses for this reason.

[0069]

Drawing 6 shows the process window of the 50nm high density line in TE polarization and immersion optical system by Example 1 of this invention. The wavelength used in this example is 193nm. The refractive index of the immersion fluid to be used is water (NA=1.437) of 1.437. A use resist is Par710 on the substrate which matched in this example. Lighting is annular [of sigma=0.9/0.7]. Drawing 6 is a plot

with exposure tolerant generosity and the depth of focus. Exposure latitude [in / in this plot / the depth of focus of 0.0] shows that it is about 9.9%, and this is usable level. Use of TE radial polarization system of Example 1 of this invention obtained the improvement of 75% of exposure latitude as compared with Example 1 for a comparison. In Example 1 of this invention, the improvement of 27% of DOF is gained as compared with Example 1 for a comparison. Therefore, improvement in a process window is attained by using TE polariscope of this invention. In other depth of focuses, exposure latitude decreases with the increment in the depth of focus.

[0070]

Drawing 7 is the schematic drawing of another operation gestalt of the radial polariscope by this invention. The radial TE polariscope 70 consists of two or more plate polariscopes. The radial polariscope 70 is created by cutting the plate polariscope 72 with which priority is given to the linearly polarized light. A plate polariscope is cut to plate sector 72 a-h, in order to create the polariscope of a circular piece. Next, plate sector 72 a-h is assembled and the radial polariscope 70 is formed. By having linearly polarized light vector condition 74 a-h, therefore collecting plate sector 72 a-h by this approach, straight-line vector polarization 74 a-h rotates, and each plate sector 72 a-h forms a radial polarization configuration. However, since a plate sector is a discrete element, in order to acquire "continuous" TE radial polarization, it is desirable to rotate a polariscope 70, to randomize the difference of the optical path between plates, and to guarantee homogeneity. Although rotation of a polariscope is not required, depending on the case, this can apply homogeneity, and according to the rotational implementation approach, rotational speed can be chosen so that it may become a high speed in a low speed or an emergency very much. In order to perform such rotation, for example, an air bearing can be equipped with a polariscope 70. When it is the EUV lithography of a lithography system whose part is a vacuum at least, the alternative wearing approach can be offered. For example, the magnetic bearing system instead of an air bearing can be equipped with a polariscope 70. Rotational speed will govern the homogeneity of polarization. Generally, although the difference of the optical path between plates is randomized, rotational speed must be high enough, in order to guarantee homogeneity.

[0071]

Drawing 8 shows roughly the alternative implementation gestalt of the lithography system which uses the radial TE polariscope of this invention. As mentioned above, the lithography system 80 is equipped with lighting or the radiation system source 81, a mask or a reticle 82, the projection lens 82, a substrate or a wafer 84, and the radial TE polariscopes 20, 30, or 70. Although the radial TE polariscopes 20, 30, or 70 are illustrated with this operation gestalt so that it may be located in the inlet port of a projection lens, and it is optimal that it is near the pupil side, it is understood by this contractor that the radial polariscopes 20, 30, or 70 can be arranged on the location of the arbitration of a projection lens or the outsides of a projection lens, such as between a reticle or a mask 82, and the projection lenses 83.

[0072]

The best performance of a radial polariscope is attained when a polariscope is an ideal polariscope which has a conductive grid (for example, a wire grid or a long and slender element) completely. In this situation, a radial polariscope functions as Miller who reflects completely the light of one polarization (for example, TM polarization), and it is completely transparent to the light of polarization (for example, TE polarization) of another side. Desired polarization (TE polarization) penetrates and the polarization (TM polarization) which is not desirable is reflected.

[0073]

However, if the radial polariscope K is arranged between a reticle 82 and the projection lens 83, the reflected light which has the polarization (TM polarization) which is not desirable, for example will return to a reticle 82. It collides, it reflects in a reticle 82 and the reflected light which has the polarization which is not desirable returns to a radial polariscope. In this process, the polarization of a part of light reflected by the reticle may change. For example, the polarization of light which the reticle 82 reflected can penetrate this part of the light which has TE polarization (secondary light) with a radial polariscope, if a part of light changes to TE polarization (desirable polarization) at least. It is because the radial polariscope is built so that the light which has TE polarization can be passed. Although this part of TE polarization has brightness lower than the light (primaryTE polarization) which has TE polarization which penetrated the radial polariscope first, it can pass a radial polariscope and, finally can reach a substrate 84. This reflex can change polarization on the way between radial polariscopes many times repeatedly. Thereby, the flare is generated in polarization. It is because secondaryTE polarization is added to TE polarization (primaryTE polarization) which crossed the radial polariscope first. Finally the polarization flare makes **** indistinct, therefore

reduces the resolution of ****.
[0074]
In order to suppress to minimum possibility that the polarization flare will be generated in ****, the artificer judged that it could use for reducing the back reflection from a polariscope, and other bodies 82 of lithography equipment, for example, a reticle, when the electric conduction grid (for example, wire grid) of a radial polariscope was covered with the layer of a thin absorber.
[0075]
This absorber layer is covered with option by the grid 22 of the radial polariscope 20 shown by drawing 2 A with one operation gestalt. A grid 22 is good with the electric conduction element created in aluminum, chromium, silver, gold, or its combination. The layer of a thin absorber is good at the ingredient 2O3 absorbed on the wavelength of the radiation to be used, for example, aluminum, and anodized aluminum. The layer of a thin absorber can also contain a compound with a low reflection factor. The suitable compound with a low reflection factor is good at BILATAL created in the process of Zeiss of Germany. There are AlN and CrOx (x is an integer) in other suitable low reflection factor compounds.
[0076]
By covering the grid 22 of a polariscope with the layer of a thin absorber, the amount in which a radial polariscope and the back reflection (secondaryTE polarization) from a reticle are absorbed by the film, and primaryTE polarization is absorbed by the layer of a thin absorber is the minimum. The light (secondaryTE polarization) of back reflection is brightness lower than primaryTE polarization, and this is because it is absorbed comparatively easily by the layer of a thin absorber. Since the extinction coefficient of a request of secondary back reflection TE polarization is attained, the thickness and/or the ingredient of an absorber layer can be chosen or adjusted.
[0077]
Although reference has been made with the above instantiation-operation gestalt about absorbing the back reflection generated between the radial polariscope and the reticle, please understand that the above is applied also in the case of back reflection which is generated between the objects of arbitration and radial polariscopes on the way of the reflected polarization.
[0078]
By using an absorption medium combining a radial polariscope, the above-mentioned process of deleting the polarization which is not desirable is useful for the **** application which uses a penetrable lithography tool, and the example is illustrated by drawing 1 . However, in the case of a reflexibility lithography tool, another configuration is used in order to delete the polarization which is not desirable. In reflexibility lithography, what is used for **** is the reflected polarization. Therefore, what it absorbs or is deleted is transmitted polarization which is not desirable.
[0079]
The schematic drawing of the polariscope which has an absorber by 1 operation gestalt of drawing 9 A this invention is shown. A polariscope 90 contains the polarization component 92 and an absorber 94. An absorber 94 is arranged behind the polarization component 92 to incident light 96. An absorber 94 can contact the tooth back of the polarization component 92, and directly, or can be slightly ****(ed) from the polariscope element 94. An absorber 94 contains the ingredient absorbed on the wavelength of the radiation to be used, i.e., the wavelength of incident light 96. Incident light 96 includes both polarization of TE component, and polarization of TM component.
[0080]
As mentioned above, in reflexibility lithography, the reflected polarization is used for **** and the transmitted polarization is penetrated. In this case, it reflects with the polarization component 92, for example, TE polarization component 97 (desirable polarization) penetrates TM polarization component 98 (polarization which is not desirable) with the polarization component 92.
[0081]
Transmitted TM polarization may encounter other optical **** elements of an object, for example, lithography equipment, on the way. Therefore, back reflection of a part of TM polarization can be carried out to the polarization component 92. Since the part of this TM polarization is "transparence" to TM polarization, the polarization component 92 crosses the polarization component 92. Although this part of TM polarization has brightness lower than TE polarization (desirable polarization), it joins desirable TE polarization, it mixes with it, and the resolution of **** may be degraded.
[0082]
An absorber 94 is introduced into the optical path of the TM polarization 98 which is not desirable in order

to reduce the back reflection which may be produced from other optical elements of a lithography tool. By this approach, TM polarization is absorbed by the absorber 94 along with the thickness ta of an absorber 94, and does not reach the object of lithography equipment which reflects TM polarization. Moreover, even if TM polarization is not completely eliminated through the thickness ta of an absorber 94 at the 1st path of light, the remaining part of the TM polarization 99 reflected by base 94B of an absorber 94 is absorbable through the thickness ta of an absorber 94 at the 2nd path. Therefore, with an absorber 94, TM polarization which is not desirable is absorbed twice and brings about rectangular absorption / quenching of TM polarization component. Quenching of TM polarization component can be strengthened by this. The thickness ta and/or the ingredient of an absorber can be chosen or adjusted so that desirable quenching of secondary back reflection TE polarization may be attained.

[0083]

With an alternative implementation gestalt, the polarization component 92 can be arranged in the crowning of the penetrable substrate instead of an absorber 94. When the polarization component 92 has been arranged in the crowning of a penetrable substrate, a quarter-wave length plate is arranged behind a substrate, and TM polarization which is not desirable is absorbed. With any operation gestalt, quenching of TM polarization component is attained by incorporating an absorber, and this is an absorptivity ingredient or a quarter-wave length plate. Furthermore, a quarter-wave length plate may be arranged between the polarization component 92 and an absorber 94. In this case, TM polarization which is not desirable encounters a quarter-wave length plate, and it becomes the circular polarization of light by passing a quarter-wave length plate. The greater part of this circular polarization of light is absorbed by the absorber 94. However, when there is light which carries out back reflection on the front face of an absorber 94, this reflected light is sent to a quarter-wave length plate, and polarizes circularly again, therefore changes to TE polarization. Since the polarization component 92 reflects TE polarization, it reflects with the polarization component 92 and the light which passes a quarter-wave length plate twice is sent to an absorber 94. By this approach, this reflected light is absorbed twice by the absorber 94. This raises deletion or quenching of the polarization component which is not desirable, i.e., TM polarization.

[0084]

The polarization component 92 shown in drawing 9 A can have the structure of grid polariscope 92A as roughly shown by drawing 9 B, or the structure of ring polariscope 92B as roughly shown by drawing 9 C. Grid polariscope 92A is the same as that of the radial polariscope 20 shown by drawing 2 A, and is good. Grid polariscope 92A has the periodic lattice 93 arranged by the pattern of the radial symmetry ****(ed) by the azimuth. The arrow head of the continuous line of drawing 9 B shows the configuration/the direction of TE polarization component, and the arrow head of a dotted line shows the configuration/the direction of TM polarization component. As mentioned above, the component polarization which has the direction of a right angle to a grid (a gridline or long and slender element) is penetrated, and a polarization component parallel to a gridline is reflected. Therefore, grid polariscope 92A is the polariscope which TM polarization reflects and TE polarization penetrates. Finally TE polarization is absorbed by the absorber 94 (it illustrates by drawing 9 A). In this case, the component used for **** is TM polarization component. However, this configuration of the absorption element 92 is rarely used with reflexibility lithography.

[0085]

On the other hand, the configuration of ring polariscope 92B shown in drawing 9 C is most used with reflexibility lithography. Ring polariscope 92B has a ring 95, and as inquired above, this can be arranged on an absorber 94 (it illustrates to drawing 9 A), or can be arranged on a penetrable substrate. A ring 95 is arranged on a concentric circle and ****(ed) periodically. The arrow head of the continuous line of drawing 9 C is an example about the configuration/the direction of TE polarization component. A dotted line shows the configuration/the direction of TM polarization component. As mentioned above, the component polarization which has the direction of a right angle to the tangent of a right angle, i.e., a ring, in a grid is penetrated, and the polarization component which carries out a tangent to a ring is reflected. In this case, TM polarization penetrates and TE polarization reflects. Finally TM polarization is absorbed by the absorber 94 (it illustrates by drawing 9 A). In this case, the component used for **** is TE polarization component.

[0086]

If drawing 10 is referred to, the device manufacture approach by this invention In order to give a pattern to the thing S110 to establish for the substrate partially covered in the layer of a radiosensitivity ingredient at least, the thing S120 established for a projection radiation beam using a radiation system, and the cross section of a projection beam, The thing S130 for which a patterning device is used, the thing S140 for which the radiation beam which carried out pattern formation is projected on the target part of the layer of a

radiosensitivity ingredient, and the thing S150 polarized in a radiation beam by longitudinal direction electrical-and-electric-equipment polarization are included.

[0087]

Drawing 11 is the schematic drawing of another operation gestalt of the polariscope 100 by this invention used in order to generate tangent polarization. It is known that polarization units, such as a beam division cube, will be used for the conventional polarization system. A beam division cube consists of one pair of fused silica precision rectangular prisms stuck carefully, in order to make distortion of a wave front into min. One oblique side of prism is covered with multilayer polarization beam splitter coatings (birefringence ingredient etc.) optimized according to specific wavelength. A beam splitter throws away the incident light of a certain amount, and the linearly polarized light of the light is carried out in one side of two branches at the outlet of a cube. Since conventionally prevents the difference of printing of a horizontal line and a vertical line, polarization becomes a round shape on the quarter-wave length plate in the pupil of a **** system.

[0088]

However, as mentioned above, the circular polarization of light consists of both fundamental polarization components TE and TM. According to this invention, the polariscope plate 102 is introduced into the pupil of a **** system equipped with the cube beam splitter 103. The plate polariscope 102 is equipped with two 1/2-wave plates 104A and 104B with 1 operation gestalt. The plate polariscope 102 polarizes, and makes the linearly polarized light the 1st s-polarized light S1 and the 2nd s-polarized light S2, therefore the wave vector S1 of the 1st s-polarized light and its wave vector S2 of the 2nd polarization are right-angled to mutual. A plate polariscope is arranged at the edge of the cube beam splitter 103, therefore one polarization direction is restricted only to two 1/4 parts of a pupil. This is not suitable for printing of a horizontal line. It is because polarization reaches a wafer as s-polarized light. In other two quadrants, about 1/2 wave of phase gap is introduced through a birefringence (less than 45 degrees). 90 degrees rotates and the polarization which is sagittal (sagital) also becomes a tangent. This is suitable for printing of a vertical line. That is, the 1st s-polarized light S1 is used, it is horizontal, a line is printed on a wafer, the 2nd s-polarized light S2 is used, it is perpendicular and a line is printed on a wafer. By this approach, S polarization or TE polarization is acquired about both a vertical line and a horizontal line.

[0089]

Furthermore, since much deformation and modification occur to this contractor easily, it is not desirable to restrict this invention to the exact structure and the actuation which were explained on these specifications. Furthermore, the process, the approach, and equipment of this invention have the inclination for a property to become complicated as well as the equipment of relation and the process which are used with a lithography technique, and in order to determine the suitable value of an operation parameter experientially or to reach the highest design for the application of arbitration, it practices the optimal by performing computer simulation in many cases. Therefore, it is considered that all suitable deformation and equivalents are the things included in the pneuma and the range of this invention.

[Brief Description of the Drawings]

[0090]

[Drawing 1] The lithography projection equipment by the operation gestalt of this invention is shown roughly.

[Drawing 2 A] It is the schematic drawing of the radial polariscope by the operation gestalt of this invention.

[Drawing 2 B] It is the enlarged drawing of the grid in the area of the polariscope shown by drawing 2 A.

[Drawing 3] It is the expansion side elevation of the radial polariscope by another operation gestalt of this invention.

[Drawing 4] It is the vector diagram showing the output and the desirable polarization direction of [from TE polariscope by the operation gestalt shown by drawing 2 A and drawing 3].

[Drawing 5] It is a plot with the exposure latitude of Example 1 for a comparison, and the depth of focus.

[Drawing 6] It is a plot with the exposure latitude of Example 1 of this invention, and the depth of focus.

[Drawing 7] It is the schematic drawing of the radial polariscope by the alternative implementation gestalt of this invention.

[Drawing 8] The operation gestalt of the lithography system which uses the radial TE polariscope of this invention is shown roughly.

[Drawing 9 A] The schematic drawing of the longitudinal direction polariscope which has the polarization component and absorber by another operation gestalt of this invention is shown.

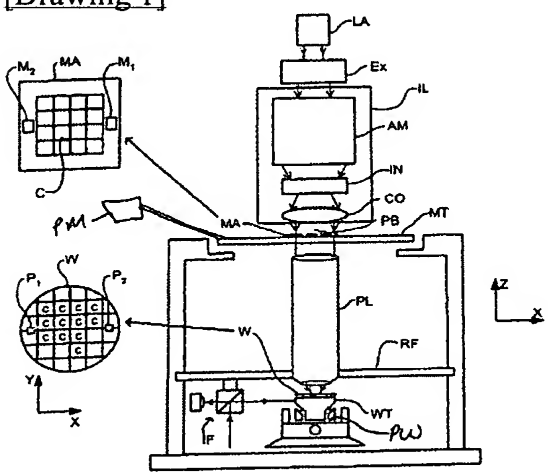
[Drawing 9 B] The schematic drawing of the operation gestalt of the polarization component used with the polariscope of drawing 9 A is shown.
[Drawing 9 C] The schematic drawing of another operation gestalt of the polarization component used for the polariscope of drawing 9 A is shown.
[Drawing 10] It is a flow chart showing the device manufacture approach by this invention.
[Drawing 11] It is the schematic drawing of another operation gestalt of the polariscope by this invention.

[Translation done.]

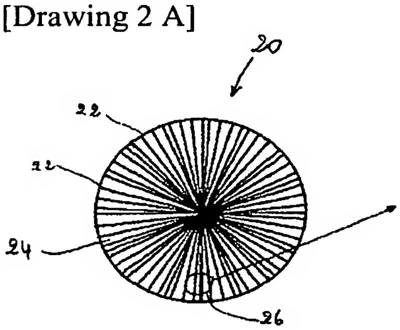
* NOTICES *

DRAWINGS

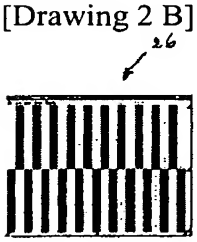
[Drawing 1]



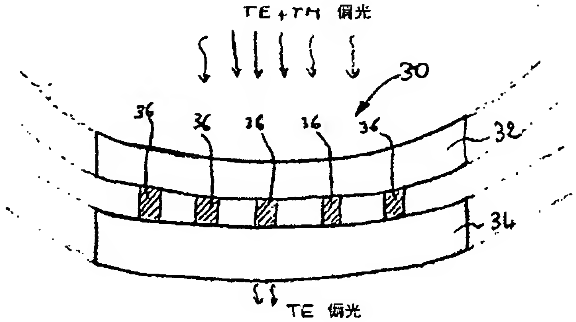
[Drawing 2 A]



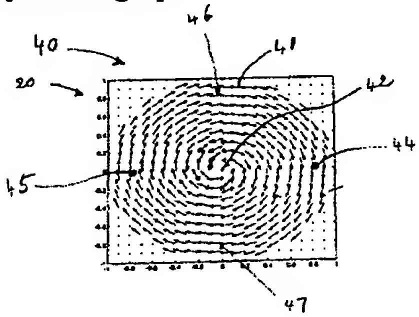
[Drawing 2 B]



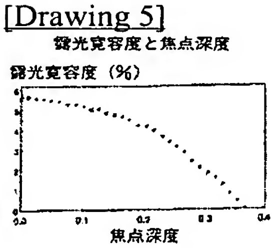
[Drawing 3]



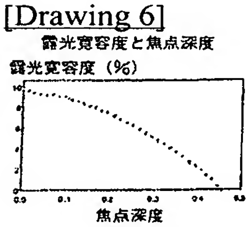
[Drawing 4]



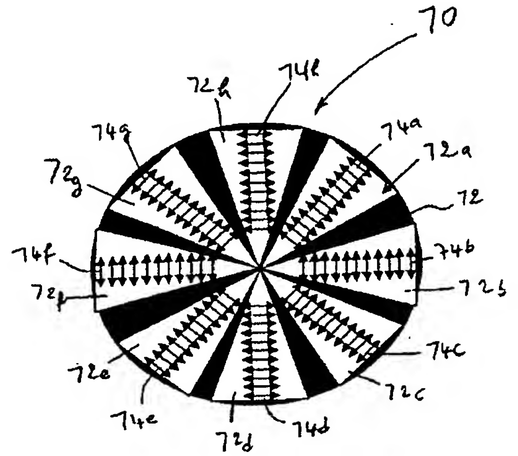
[Drawing 5]



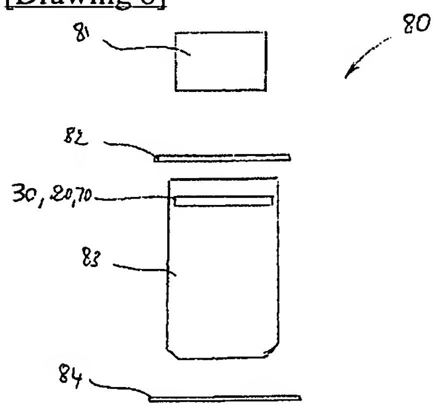
[Drawing 6]



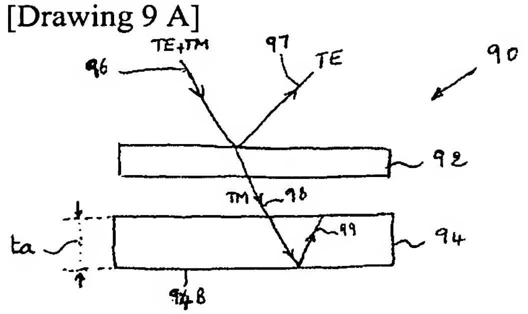
[Drawing 7]



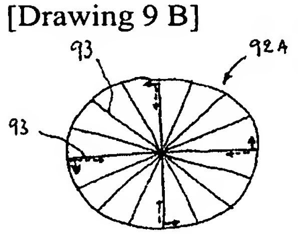
[Drawing 8]



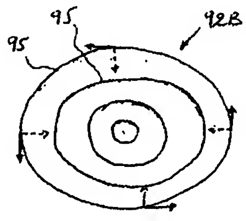
[Drawing 9 A]



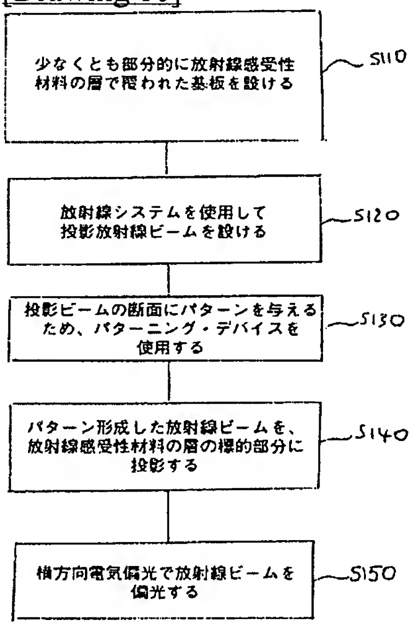
[Drawing 9 B]



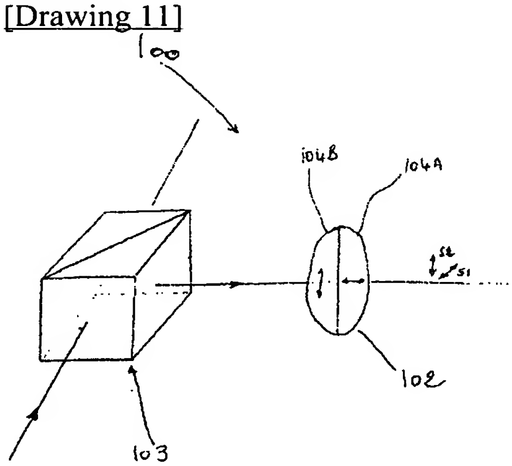
[Drawing 9 C]



[Drawing 10]



[Drawing 11]



[Translation done.]

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1. ポラロイド

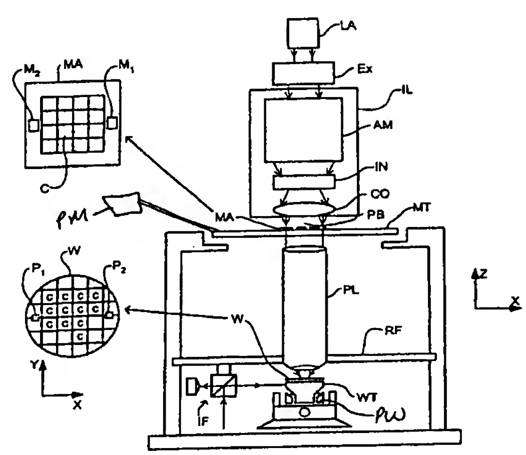
(71)出願人 502010332
エイエスエムエル ネザランドズ ベスローテン フエンノートシャップ
オランダ国 5503 エルエイ フェルトホーフェン, デ ルン 1110
(74)代理人 100066692
弁理士 浅村 皓
(74)代理人 100072040
弁理士 浅村 肇
(74)代理人 100087217
弁理士 吉田 裕
(74)代理人 100080263
弁理士 岩本 行夫

最終頁に続く

(54)【発明の名称】高開口数システムの固定および動的ラジアル横方向電気偏光器

(57)【要約】
【課題】第1屈折率を有する材料の第1層、第2屈折率を有する材料の第2層、および方位角で周期的に隔置されて第1層と第2層との間に配置された複数の細長い要素を含むラジアル横方向電気偏光器装置を提供すること。

【解決手段】ラジアル横方向電気偏光器は、第1屈折率を有する材料の第1層と、第2屈折率を有する材料の第2層と、方位角で周期的に隔置され、第1層と第2層との間に配置された複数の細長い要素とを含む。複数の細長い要素が、放射線の電磁波と相互作用して、放射線の電磁波の横方向電気偏光を透過する。偏光器デバイスは、例えばリソグラフィ投影装置に使用して、描像の解像度を上げることができる。デバイス製造方法は、放射線ビームを横方向電気偏光で偏光することを含む。



【選択図】図1

【特許請求の範囲】
【請求項１】
ラジアル横方向電気偏光器デバイスで、
第１屈折率を有する材料の第１層と、
第２屈折率を有する材料の第２層と、
方位角で周期的に隔置され、前記第１層と前記第２層との間に配置された複数の細長い要素とを備え、
前記複数の細長い要素が放射線の電磁波と相互作用して、放射線の電磁波の横方向電気偏光を透過するラジアル横方向電気偏光器デバイス。
【請求項２】
前記第１屈折率が前記第２屈折率と等しい、請求項１に記載のラジアル横方向電気偏光器デバイス。
【請求項３】
前記複数の細長い要素が複数のギャップを形成する、請求項１に記載のラジアル横方向電気偏光器デバイス。
【請求項４】
前記ギャップが空気を含む、請求項３に記載のラジアル横方向電気偏光器デバイス。
【請求項５】
前記ギャップが、第３屈折率を有する材料を含む、請求項３に記載のラジアル横方向電気偏光器デバイス。
【請求項６】
前記細長い要素が第４屈折率を有する、請求項１に記載のラジアル横方向電気偏光器デバイス。
【請求項７】
前記細長い要素が、前記光の電磁波を横方向電気偏光で偏光するよう選択された周期で周期的に隔置される、請求項１に記載のラジアル横方向電気偏光器デバイス。
【請求項８】
前記電磁放射線が紫外線である、請求項１に記載のラジアル横方向電気偏光器デバイス。
【請求項９】
ラジアル横方向電気偏光器デバイスで、
第１屈折率を有する基板材料と、
前記基板材料に結合され、方位角で配向された複数の細長い要素とを備え、前記細長い要素が第２屈折率を有し、
前記複数の要素が、周期的に隔置されて複数のギャップを形成し、したがって前記ラジアル横方向電気分極器デバイスが、第１および第２偏光を備えた電磁放射線と相互作用して、第１偏光の放射線をほぼ全て反射し、第２偏光の放射線をほぼ全て透過するラジアル横方向電気偏光器デバイス。
【請求項１０】
前記第１偏光が横方向磁気偏光であり、前記第２偏光が横方向電気偏光である、請求項９に記載のラジアル横方向電気偏光器デバイス。
【請求項１１】
前記複数の細長い要素が、前記電磁放射線での波長で導電性の材料で形成される、請求項９に記載のラジアル横方向電気偏光器デバイス。
【請求項１２】
前記導電性の材料が、アルミ、クロム、銀および金のグループから選択される、請求項１１に記載のラジアル横方向電気偏光器デバイス。
【請求項１３】
前記基板材料が、前記電磁放射線の波長で誘電性の材料で形成される、請求項9に記載のラジアル横方向電気偏光器デバイス。

【請求項１４】
前記誘電性材料が、二酸化珪素、酸化シリコン、窒化シリコン、ガリウム砒素およびその組合せのグループから選択される、請求項１３に記載のラジアル横方向電気偏光器デバイス。
【請求項１５】
前記基板材料が誘電性材料を備える、請求項９に記載のラジアル横方向電気偏光器デバイス。
【請求項１６】
さらに、
吸収性材料の薄い層を備え、前記吸収性材料の薄い層が、前記電磁放射線の波長で放射線を吸収し、
前記複数の細長い要素が、前記吸収性材料の薄い層で被覆される、請求項９に記載のラジアル横方向電気偏光器デバイス。
【請求項１７】
第２放射線の２次放射線に変化した第１偏光の反射放射線の一部が、前記吸収性材料の薄い層によってほぼ吸収される、請求項１６に記載のラジアル横方向電気偏光器デバイス。
【請求項１８】
第２偏光の放射線が、前記吸収性材料の薄い層によって最少量だけ吸収される、請求項１７に記載のラジアル横方向電気偏光器デバイス。
【請求項１９】
前記吸収性材料の薄い層が、第２放射線の等価放射線にある偏光のフレアをほぼ解消する、請求項１８に記載のラジアル横方向電気偏光器デバイス。
【請求項２０】
第２偏光が横方向電気偏光である、請求項９に記載のラジアル横方向電気偏光器デバイス。
【請求項２１】
前記吸収性材料の薄い層が、Al_2O_3および陽極酸化アルミのグループから選択される、請求項１６に記載のラジアル横方向電気偏光器デバイス。
【請求項２２】
リソグラフィ投影装置で、
放射線の投影ビームを提供するよう構成された放射線システムと、
パターニング・デバイスを支持するよう構成された支持構造とを備え、パターニング・デバイスが、所望のパターンに従って投影ビームにパターン形成するよう構成され、さらに、
基板を保持するよう構成された基板テーブルと、
パターン形成したビームを基板の標的部分に投影するよう構成された投影システムと、
前記放射線ビームを横方向電気偏光の方向で偏光するよう構築され、配置された偏光器デバイスとを備えるリソグラフィ投影装置。
【請求項２３】
前記偏光器デバイスが、
第１屈折率を有する材料の第１層と、
第２屈折率を有する材料の第２層と、
方位角で周期的に隔置され、前記第１層と前記第２層との間に配置された複数の細長い要素とを備え、
前記複数の細長い要素が、前記放射線ビームと相互作用して、前記放射線ビームの横方向電気偏光を透過する、請求項２２に記載のリソグラフィ投影装置。
【請求項２４】
前記偏光器デバイスが、
第１屈折率を有する基板材料と、

前記基板材料に結合され、方位角で配向された複数の細長い要素とを備え、前記細長い要素が第２屈折率を有し、

前記複数の要素が周期的に隔置されて、複数のギャップを形成し、したがって前記ラジアル横方向電気偏光器デバイスが、第１および第２偏光を備えた放射線ビームと相互作用して、第１偏光の放射線をほぼ全て反射し、第２偏光の放射線をほぼ全て透過する、請求項２２に記載のリソグラフィ投影装置。

【請求項２５】

前記偏光器デバイスがさらに、吸収性材料の薄い層を備え、前記吸収性材料の薄い層が、前記電磁放射線の波長で放射線を吸収し、

前記複数の細長い要素が、前記吸収性材料の薄い層で被覆される、請求項２４に記載のリソグラフィ投影装置。

【請求項２６】

第２偏光の２次放射線に変化した第１偏光の反射放射線の部分が、前記吸収性材料の薄い層によってほぼ吸収されるよう、前記吸収性材料の薄い層が選択される、請求項２５に記載のリソグラフィ投影装置。

【請求項２７】

第２偏光の放射線が、前記吸収性材料の薄い層によって最少量だけ吸収される、請求項２６に記載のリソグラフィ投影装置。

【請求項２８】

前記吸収性材料の薄い層が、第２偏光の透過放射線の偏光フレアをほぼ解消する、請求項２７に記載のリソグラフィ投影装置。

【請求項２９】

第２偏光が横方向電気偏光である、請求項２５に記載のリソグラフィ投影装置。

【請求項３０】

前記吸収性材料の薄い層が、Al_2O_3および陽極酸化アルミのグループから選択される、請求項２５に記載のリソグラフィ投影装置。

【請求項３１】

前記放射線ビームの波長範囲が、紫外線スペクトル内にある、請求項２２に記載のリソグラフィ投影装置。

【請求項３２】

前記波長範囲が３６５ｎｍと１２６ｎｍの間である、請求項３１に記載のリソグラフィ投影装置。

【請求項３３】

前記波長範囲が超紫外線にある、請求項３１に記載のリソグラフィ投影装置。

【請求項３４】

第１および第２偏光を備えた電磁放射線と相互作用して、第１偏光の放射線のほぼ全てを反射し、第２偏光の放射線のほぼ全ての透過するラジアル横方向電気偏光器デバイスで、

それぞれが複数の平行な直線偏光方向を画定する複数のセクタ形の直線偏光器プレートを備え、

前記複数のセクタ形の直線偏光器プレートが方位角で配置され、したがって前記複数の平行な直線偏光方向が回転し、ラジアル偏光構成を形成する偏光器デバイス。

【請求項３５】

前記ラジアル横方向偏光器が、前記ラジアル横方向偏光器によって画定された面に対して直角な軸線を中心として回転するよう構築され、配置される、請求項３４に記載のラジアル横方向電気偏光器デバイス。

【請求項３６】

デバイス製造方法で、

パターン形成した放射線ビームを、少なくとも部分的に基板を覆う放射線感受性材料の層の標的部分に投影することと、

横方向電気偏光で前記放射線ビームを分極することとを備える方法。
【請求項３７】
請求項３６に記載の方法により製造したデバイス。
【請求項３８】
接線偏光器デバイスで、
入射光の少なくとも一部を直線偏光に偏光するよう構築され、配置されたキューブ・ビーム・スプリッタ偏光器と、
２つの１／２波長プレートを備える偏光プレートとを備え、
前記偏光プレートが、前記キューブ・ビーム・スプリッタ偏光器の端部に配置されて、前記直線偏光を第１ｓ偏光と第２ｓ偏光とに偏光し、したがって前記第１ｓ偏光の波ベクトルおよび前記第２ｓ偏光の波ベクトルが、相互に対して直角である接線偏光器デバイス。
【請求項３９】
前記第１ｓ偏光を使用して、水平方向でウェハ上に線を印刷し、前記第２ｓ偏光を使用して、垂直方向でウェハ上に線を印刷する、請求項３８に記載の接線偏光器デバイス。
【請求項４０】
偏光器デバイスで、
偏光コンポーネントと、
前記偏光コンポーネントの後方に配置された吸収体とを備え、
前記偏光コンポーネントが、第１および第２偏光を備えた電磁放射線と相互作用して、第１偏光の放射線をほぼ全て反射し、第２偏光の放射線をほぼ全て透過して、前記吸収体が、前記電磁放射線の波長で吸収する材料を含み、前記材料が、前記第２偏光の放射線をほぼ全て吸収する偏光器デバイス。
【請求項４１】
前記偏光コンポーネントが、方位角で配向された複数の細長い要素を備え、前記複数の要素が、周期的に隔置されて複数のギャップを形成する、請求項４０に記載の偏光器デバイス。
【請求項４２】
前記複数の細長い要素が、電磁放射線の波長で導電性である、請求項４１に記載の偏光器デバイス。
【請求項４３】
前記第１偏光が横方向磁気偏光であり、前記第２偏光が横方向電気偏光である、請求項４０に記載の偏光器デバイス。
【請求項４４】
前記偏光コンポーネントが、同心円上に配置された複数のリングを備え、前記リングが周期的に隔置される、請求項４０に記載の偏光器デバイス。
【請求項４５】
前記第１偏光が横方向電気偏光であり、前記第２偏光が横方向磁気偏光である、請求項４４に記載の偏光器デバイス。
【請求項４６】
請求項４０に記載の変更器デバイスを使用する反射タイプリソグラフィ装置。
【請求項４７】
電磁放射線の前記波長で吸収する前記材料が、Al_2O_3および陽極酸化アルミのグループから選択される、請求項４０に記載の変更器デバイス。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は概ね光学偏光器に、特に高い開口数のリソグラフィの偏光器に関する。
【背景技術】
【０００２】

リソグラフィ投影装置は、例えば集積回路（ＩＣ）の製造に使用することができる。このような場合、パターン形成手段は、ＩＣの個々の層に対応する回路パターンを生成し、このパターンを、放射線感受性材料（レジスト）の層で被覆した基板（シリコン・ウェハ）上の標的部分（例えば１つまたは複数のダイを備える）に描像することができる。概して、１枚のウェハまたは基板が、１回に１つずつ投影システムを介して連続的に照射される隣接標的部分の全ネットワークを含む。

【０００３】

「パターニング・デバイス」という用語は、本明細書で使用すると、基板の標的部分に生成すべきパターンに対応し、パターン形成した断面を、入射放射線ビームに与えるために使用することができるデバイスを指すよう広義に解釈される。「ライトバルブ」という用語も、この文脈で使用することができる。概して、パターンは、集積回路または他のデバイスなど、標的部分に生成するデバイスの特定の機能層に対応する。

【０００４】

このようなパターニング・デバイスの一例はマスクである。マスクの概念はリソグラフィでよく知られ、バイナリ、交互位相ずれ、および減衰位相ずれ、さらに様々な複合マスク・タイプなどのマスク・タイプを含む。このようなマスクを放射線ビームに配置すると、マスク上のパターンに従いマスクに衝突する放射線の選択的透過（透過性マスクの場合）または反射（反射性マスクの場合）が生じる。マスクの場合、支持構造は概ねマスク・テーブルであり、これによりマスクを入射放射ビームの所望の位置に保持でき、所望に応じてビームに対して移動できることが保証される。

【０００５】

パターニング・デバイスの別の例はプログラマブル・ミラー・アレイである。このようなアレイの一例は、粘弾性制御層および反射性表面を有するマトリックス・アドレス指定可能表面である。このような装置の元となる原理は、例えば反射性表面のアドレス指定された区域は、屈折光として入射光を反射し、アドレス指定されない区域は非屈折光として入射光を反射することである。適切なフィルタを使用すると、非屈折光を反射ビームから除去し、屈折光のみを残すことができる。この方法で、ビームはマトリックス・アドレス指定可能表面のアドレス指定パターンに従ってパターン形成される。

【０００６】

プログラマブル・ミラー・アレイの代替実施形態は、微小なミラーのマトリックス構成を使用し、各ミラーは、局所化した適切な電界を与えるか、圧電起動手段を使用することによって軸線の周囲で個々に傾斜させることができる。この場合もミラーはマトリックス・アドレス指定可能であり、したがってアドレス指定されたミラーは、アドレス指定されないミラーとは異なる方向に放射ビームを反射する。この方法により、反射ビームはマトリックス・アドレス指定可能ミラーのアドレス指定パターンに従ってパターン形成される。必要なマトリックス・アドレス指定は、適切な電子機器を使用して実施することができる。上述した状況の双方で、パターニング・デバイスは、１つまたは複数のプログラマブル・ミラー・アレイを備えることができる。本明細書で言及するミラー・アレイに関する詳細な情報は、例えば米国特許第５，２９６，８９１号および米国特許第５，５２３，１９３号および国際ＰＣＴ特許出願第９８／３８５９７号および第９８／３３０９６号で収集することができる。プログラマブル・ミラー・アレイの場合、支持構造は、必要に応じて固定するか動作可能なフレームまたはテーブルなどとして実現してもよい。

【０００７】

パターニング・デバイスの別の例はプログラマブルＬＣＤアレイである。このような構造の一例が米国特許第５，２２９，８７２号で与えられている。上記と同様、この場合の支持構造は、必要に応じて固定するか動作可能なフレームまたはテーブルなどとして実現してもよい。

【０００８】

単純にするため、本明細書ではこれ以降、特定の箇所で、マスクおよびマスク・テーブルに関わる例を特に指向する。しかし、このような場合に検討される一般原理は、以上で

記述したようなパターニング・デバイスという、より広義の文脈で考慮されたい。

【０００９】

マスク・テーブル上のマスクによるパターン形成を使用するこの装置では、２つの異なるタイプの機械を区別することができる。一方のタイプのリソグラフィ投影装置では、マスク・パターン全体を１回で標的部分に曝露させることにより、各標的部分に照射する。このような装置は通常、ウェハ・ステッパと呼ばれる。一般に走査ステップ式装置と呼ばれる代替装置では、投影ビームの下で任意の基準方向（「走査」方向）でマスク・パターンを漸進的に走査しながら、この方向に平行または逆平行に基板テーブルを同期走査することにより、各標的部分に照射する。概して、投影システムは倍率Ｍ（概ね＜１）を有するので、基板テーブルを走査する速度Ｖは、係数Ｍにマスク・テーブルを走査する速度を掛ける値となる。本明細書で説明するようなリソグラフィ装置に関する詳細な情報は、例えば参照により本明細書に組み込まれる米国特許第６，０４６，７９２号で見ることができる。

【００１０】

リソグラフィ投影装置を使用する既知の製造プロセスでは、少なくとも部分的に放射線感受性材料（レジスト）の層で覆われた基板に、（例えばマスクの）パターンを描像する。この描像ステップの前に、基板にはプライミング、レジスト被覆およびソフト・ベークなどの様々な手順を実施してよい。露光後、基板は、撮像した特徴の現像前ベーク（ＰＥＢ）、現像、ハード・ベークおよび測定／検査など、他の手順を実施することができる。この一連の手順は、例えばＩＣなど、デバイスの個々の層にパターン形成するためのベースとして使用する。このようなパターン形成した層は、次にエッチング、イオン注入（ドーピング）、メタライゼーション、酸化、化学、機械的研磨などの様々なプロセスを実施することができ、これらは全て、個々の層を仕上げるよう意図されている。数層が必要な場合は、手順全体またはその変形を新しい層ごとに反復しなければならず、積み重ねた様々な層のオーバレイ（並置）を、可能な限り正確に実行する。そのために、ウェハの１つまたは複数の位置に小さい基準マークを設け、したがってウェハ上に座標系の起点を画定する。光学および電子デバイスを基板ホルダの位置決め装置（以下で「アライメント・システム」と呼ぶ）と組み合わせて使用すると、新しい層を既存の層に並置させるたびに、このマークを再配置し、アライメント基準として使用することができる。最終的に、アレイ状のデバイスが基板（ウェハ）上に存在する。次にこれらのデバイスを、ダイシングまたはソーイングなどの技術によって相互から分離し、ここで個々のデバイスをキャリア上に装着したり、ピンに接続したりすることができる。このようなプロセスに関するさらなる情報は、例えばPeter van Zant著の「Microchip Fabrication: A Practical Guide to Semiconductor Processing」第３版(McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4)という著書から獲得することができる。

【００１１】

単純にするため、投影システムをこれ以降「レンズ」と呼ぶ。しかしこの用語は、例えば屈折光学系、反射光学系および反射屈折光学系など、様々なタイプの投影システムを含むものと広義に解釈されたい。放射線システムは、投影放射ビームを配向、成形、または制御するため、これらの設計タイプのいずれかにより動作するコンポーネントも含むことができ、このようなコンポーネントは、以下で集合的または単独で「レンズ」とも呼ぶことができる。さらに、リソグラフィ装置は、２つ以上の基板テーブル（および／または２つ以上のマスク・テーブル）を有するタイプでもよい。このような「複数ステージ」のデバイスでは、追加テーブルを平行にして使用するか、１つまたは複数のテーブルで予備ステップを実施しながら、１つまたは複数のテーブルを露光に使用する。二重ステージ・リソグラフィ装置は、例えば米国特許第５，９６９，４４１号および第６，２６２，７９６号に記載されている。

【００１２】

リソグラフィで新しいツールおよび方法が開発されると、ＩＣなどのデバイス上にパターン形成される描像機構の解像度が改善される。光学リソグラフィのツールと技術は、改

善され続け、場合によっては５０ｎｍ未満の解像度にまでなる。これは、比較的高い開口数（ＮＡ）のレンズ（０．７５ＮＡ以上）、１５７ｎｍしかない波長、および位相ずれマスク、従来とは異なる照明および進歩したフォトレジスト・プロセスなどのおびただしい技術を使用して達成することができる。

【００１３】

このような波長より小さい解像度での製造プロセスを成功させるには、低変調画像を印刷する能力、または許容可能なリソグラフィの歩留まりを出すレベルまで画像変調を増加させる能力を利用する。

【００１４】

通常、産業はレイリー基準を使用して、プロセスの解像度および焦点深度の機能を評価してきた。解像度および焦点深度（ＤＯＦ）は下式によって与えられる。

解像度＝k_1（λ／ＮＡ）

および

ＤＯＦ＝k_2（λ／ＮＡ^2）

ここでλは照明ソースの波長であり、k_1およびk_2は特定のリソグラフィ・プロセスの定数である。

【００１５】

したがって、特定の波長では、使用するツールのＮＡを高くして解像度が上がるにつれ、焦点深度を短くすることができる。高いＮＡでＤＯＦが失われることが、よく知られている。しかし、ＮＡが高く部分的にコヒーレントなシステムの偏光標的は検査されていない。下式に従う。

【数１】

$$I(r, Z_0) = \sum_i \int_s d\rho\, J(\rho_0) \left| FT \left\{ O(\rho-\rho_0)\, P_i(\rho)\, F_i(\rho,z)\, H(\rho,Z_0) \right. \right.$$

【００１６】

ここで像Ｉは、フォトレジストなどの任意のフィルムでは、位置ｒの関数であり、任意の焦点位置Z_0に特有である。この式は全てのＮＡについて有効であり、像が全ての偏光状態ｉの合計である。積分は、Ｊによって定義されたソースの分布にわたって実行される。ブラケット内のフーリエ項は、射出ひとみにおける電界分布を示す。ブラケット内の４つの項はそれぞれ、レチクル・パターンのオブジェクト・スペクトルＯ、偏光関数Ｐ、フィルムの関数Ｆ、およびひとみ関数Ｈである。

【００１７】

この式によると、高いＮＡの描像は、本質的に偏光状態および薄膜構造に関連付けられ、ここでフォトレジスト・フィルムが吸収するパワーおよび電界結合を、徹底的に変化させることができる。フォトレジスト・フィルム上の入射面波により吸収されるパワーは、フィルムの現像に必要な露光に比例する。

【００１８】

２００２年２月２７日から３月３日に米国カリフォルニア州サンタクララで開催された第２５回Annual International Symposium on Microlithography (SPIE)で「Optical Lithography into the Millennium: Sensitivity to Aberrations, Vibrations and Polarization」という表題で発表されたDonis G. Flagelloその他の研究は、２つの直交する偏光（横方向電気偏光ＴＥおよび横方向磁気偏光ＴＭ）が高いＮＡで最高２５％のパワー変化まで大きく発散することを示した。描像システムは複数の入射角度を含み、この効果を低下させる。しかし、交互の位相ずれマスク（ＰＳＭ）は小さい部分干渉が必要であり、これは角度の総数を制限し、したがって同様の露光変化を生じることがある。

【００１９】

シミュレーションから結果が獲得され、これは、完全に偏光した状態と偏光していない

状態との限界寸法差が、開口数ＮＡによって決定されることを示す。結果は、交互の位相ずれマスク（ＰＳＭ）での密集した線が最も重要な特徴であることも示し、これは、ひとみの構成がウェハ・レベルで２本ビームの干渉を基本的に生成し、このケースは偏光の効果を最大にする傾向があることによって説明されている。例えば（比較的高い）０．８５という開口数を選択し、系統的限界寸法ＣＤ誤差を３％未満に制限したい場合、残留偏光は１０％に制限しなければならない。限界寸法ＣＤは、線の最小幅、またはデバイスの製造において可能な２本線間の最小間隔である。シミュレーション結果は、ひとみ充填レベルおよび部分干渉が、偏光の効果を小さくできることも示す。これは、従来の照明を使用した機構への小さい偏光の影響によって示されている。

【００２０】

したがって、使用する位相マスクを多くし、小さい干渉レベルを必要とする描像技術を使用するので、レンズのより新しい測定技術が必要になることがある。例えば、高いＮＡの偏光効果の結果、リソグラフィ・ツールの照明偏光が極めて厳密に指定される。

【００２１】

「液体浸漬」と呼ばれる解像度向上技術（ＲＥＴ）の出現により、照明ソース（レーザ）またはマスク技術を変更することなく、１５７ｎｍの光学リソグラフィが７０ｎｍより十分下へ、場合によっては５０ｎｍ未満へと拡張する見込みである。２００１年１１／１２月のJ. Vac. Sci. Technology B19(6)で発表された「Immersion Lithography at 157 nm」という表題のM. Switkesその他によるマサチューセッツ工科大学（ＭＩＴ）の論文によると、液体浸漬技術は、超紫外線（ＥＵＶ）および電子投影リソグラフィ（ＥＰＬ）などの次世代リソグラフィ（ＮＧＬ）の必要性を打ち消す可能性がある。液体浸漬技術は、化学物質およびレジストを使用して、解像度を向上させる。浸漬リソグラフィは、最高で浸漬液の屈折率の開口数を有する投影光学システムの解像度を上げることができる。開口数ＮＡは、媒質の屈折率ｎと、ウェハ（$NA = n \sin\theta$）の点画像に収束する光の円錐の半角の正弦との積に等しい。したがって、屈折率ｎを増加させてＮＡを増加させると、解像度を上げることができる（解像度＝$k_1(\lambda / NA)$の式を参照）。しかし、上述したように、ＮＡが高くなると、リソグラフィ・ツールの照明偏光に対する仕様が極めて厳しくなることがある。したがって、偏光が浸漬リソグラフィに果たす役割が増大する。

【発明の開示】

【発明が解決しようとする課題】

【００２２】

第１屈折率を有する材料の第１層、第２屈折率を有する材料の第２層、および方位角で周期的に隔置されて第１層と第２層との間に配置された複数の細長い要素を含むラジアル横方向電気偏光器装置を提供することが、本発明の態様である。複数の細長い要素は、放射線の電磁波と相互作用して、放射線の電磁波の横方向電気偏光を透過する。

【課題を解決するための手段】

【００２３】

一つの実施形態では、第１屈折率は第２屈折率と等しい。別の実施形態では、複数の細長い要素が複数のギャップを形成する。これらのギャップは、例えば空気または第３屈折率を有する材料を含むことができる。さらに別の実施形態では、細長い要素は、横方向電気偏光の放射線の電磁波を偏光させるよう選択した周期で、周期的に隔置される。

【００２４】

第１屈折率を有する基板材料、および基板材料および第２屈折率を有する細長い要素と結合された複数の細長く方位角によって配向された要素を含むラジアル横方向電気偏光器デバイスを提供することが、本発明の別の態様である。複数の要素は周期的に隔置されて、複数のギャップを形成し、したがってラジアル横方向電気偏光器デバイスは、第１および第２偏光を有する電磁放射線と相互作用して、第１偏光の放射線のほぼ全てを反射し、第２偏光の放射線のほぼ全てを透過する。

【００２５】

本発明の実施形態では、第１偏光は横方向磁気偏光（ＴＭ）であり、第２偏光は横方向

電気（ＴＥ）偏光である。複数の細長い要素は、例えばアルミ、クロム、銀および金で形成することができる。基板材料は、例えばクォーツ（二酸化珪素）、酸化シリコン、窒化シリコン、ガリウム砒素、誘電材料、およびその組合せでよい。

【００２６】

本発明の別の実施形態では、ラジアル横方向電気偏光器は、任意選択でさらに吸収性材料の薄い層を含む。複数の細長い要素は、電磁放射線の波長で吸収する吸収性材料の薄い層で被覆する。吸収性材料の薄い層は、第１偏光の反射した放射線の部分で、第２偏光の２次放射線に変形している部分が、吸収性材料の薄い層によってほぼ吸収されるよう選択される。この方法で、吸収性材料の薄い層は、第２偏光の透過放射線の偏光フレア（ゆらぎ）をほぼ解消することができる。

【００２７】

本発明の別の態様は、偏光コンポーネントと、偏光コンポーネントの後方に配置された吸収体とを含む偏光器デバイスを提供することである。偏光コンポーネントは、第１および第２偏光を含む電磁放射線と相互作用して、第１偏光の放射線をほぼ全て反射し、第２偏光の放射線をほぼ全て透過する。吸収体は、電磁放射線の波長で吸収する材料を含む。材料は、第２偏光の放射線をほぼ全て吸収する。偏光器は、反射タイプのリソグラフィ装置で使用することができる。

【００２８】

一つの実施形態では、偏光コンポーネントは、方位角で配向された複数の細長い要素を含む。複数の要素は周期的に隔置されて、複数のギャップを形成する。複数の細長い要素は、例えば電磁放射線の波長で導電性であってよい。例示的実施形態では、第１偏光は横方向磁気偏光であり、第２偏光は横方向電気偏光である。

【００２９】

別の実施形態では、偏光コンポーネントは、同心状に配置されて周期的に隔置された複数のリングを含む。例示的実施形態では、第１偏光は横方向電気偏光であり、第２偏光は横方向磁気偏光である。

【００３０】

本発明の別の態様によると、リソグラフィ投影装置が提供され、装置は、投影放射線ビームを提供するよう構築され、配置された放射線システムと、パターニング・デバイスを支持するよう構築され、配置された支持構造とを含み、パターニング・デバイスは、所望のパターンに従って投影ビームにパターン形成するよう構築されて、配置され、さらに基板を保持する基板テーブルと、パターン形成したビームを基板の標的部分に投影するよう構築され、配置された投影システムと、放射線ビームを横方向電気偏光方向で偏光するよう構築され、配置された偏光器デバイスとを含む。

【００３１】

本発明のさらなる態様では、少なくとも部分的に基板を覆う放射線感受性材料の層の標的部分に、パターン形成した放射線ビームを投影することと、横方向電気偏光で放射線ビームを偏光することとを含むデバイス製造方法が提供される。本発明のさらに別の態様は、上述した方法を使用して製造したデバイスを提供することである。

【００３２】

本明細書では、本発明による装置をＩＣの製造に使用することに特に言及しているが、このような装置は、他の多くの用途が可能であることを明示的に理解されたい。例えば、集積光学システム、磁気ドメイン・メモリの案内および検出パターン、液晶表示パネル、薄膜磁気ヘッドなどに使用してもよい。このような代替用途に関して、本明細書で「レチクル」、「ウェハ」または「ダイ」という用語を使用する場合、それはそれぞれより一般的な「マスク」、「基板」および「標的部分」という用語に置換するものと考えるべきことが当業者には理解される。

【００３３】

本明細書では、「放射線」および「ビーム」という用語は、紫外線（例えば波長が３６５、２４８、１９３、１５７または１２６ｎｍ）およびＥＵＶ（超紫外線、例えば５～２

０ｎｍの範囲の波長を有する）を含む全タイプの電磁放射線、さらにイオン・ビームや電子ビームのような粒子ビームを含むよう使用される。

【００３４】

本発明の以上およびその他の目的は、本発明の現在好ましい例示的実施形態に関する以下の詳細な説明を、添付図面との関連で考慮することにより、さらに明白になり、さらに容易に理解される。

【発明を実施するための最良の形態】

【００３５】

偏光を生成するために、幾つかの技術が使用されてきた。自然構成、つまり非偏光を偏光するには、基本的に４つの技術がある。１つの技術は、複屈折または２軸材料に基づく。第２の技術は、「ポラロイド」などの２色性材料の使用に基づく。第３の技術は薄膜技術を使用し、ブルースター効果を利用する。第４の技術は、ワイヤ・グリッドまたは導電性格子に基づく。

【００３６】

複屈折材料を使用して光を偏光することは、複屈折偏光器の生産で知られている。複屈折偏光器は、多くの結晶および特定の延伸ポリマからも作成することができる。複屈折材料とは、一方向では別方向と異なる屈折率を有する材料である。２方向での屈折率の差の程度は、光の波長に従い変化する。屈折率の差を使用して、１つの直線偏光のビームを別のそれと分離する。複屈折偏光器の使用は、非効率、波長に依存する性能を特徴とし、高度に視準された光を必要とする。これらの理由から、複屈折偏光器は、光学投影システムでは一般に使用されない。

【００３７】

２色性偏光器は、一方の偏光を吸収し、他方を透過するよう設計された偏光器である。最も一般的に使用される２色性偏光器は、その分子を配向するよう延伸し、分子が一方向の偏光を吸収するよう、ヨウ素および／または他の材料または化学物質で処理されたポリマ・シートで構成される。延伸ポリマ偏光器は、一方の偏光の強度全部と、透過した偏光のうち少なくとも１５％を吸収する。延伸ポリマ偏光器は、時間とともに劣化する。というのは、光がポリマ材料の化学変化を誘発し、その結果、材料が黄色くなるか、脆弱になるからである。２色性偏光器は、熱および他の環境的変化にも敏感である。

【００３８】

この１０年間に、延伸ポリマ・シートを複屈折にした偏光器デバイスが開発された。この延伸シートは一方の偏光を反射し、他方を通過させる。この偏光器技術の一つの問題は、約１５という低い消光率である。用途によっては有用であるが、この消光率は、２次偏光器なしの描像用途には十分でない。このタイプの偏光器は、上述した環境的問題からも悩まされる。

【００３９】

薄膜偏光器技術は、ガラス、プラスチックなどのような材料の表面にブルースター角度（約４５°）で入射する光線が２つの偏光ビームに分割され、一方は透過して、他方は反射するブルースター効果を使用する。しかし、薄膜偏光器技術は、光線入射の角度範囲を制限する。許容角度範囲は、大部分のデバイスで数度と非常に狭く制限される。薄膜偏光器技術は、入射光の波長に対するブルースター角度の依存性のため、波長の依存性にも悩まされる。

【００４０】

偏光光線の応用を探る画像投影システムでは、ビームが明るい方が常に望ましい。偏光ビームの輝度は多くの要素によって決定され、要素の一つは光源自体である。偏光器を使用するシステムの別の要素は、受光角である。受光角が狭い、または制限された偏光器は、広い受光角を使用するシステムほど多くの光を発散光源から集めることができない。受光角が大きい偏光器は、投影光学システムの設計に融通性を持たせることができる。これは、偏光器を、光源に対して狭い受光角範囲内で配置し、配向する必要がないからである。

【００４１】
偏光器の別の望ましい特徴は、偏光の１つの成分を他の成分から効果的に分離することである。これは消光率と呼ばれ、望ましくない偏光成分の光の量に対する所望の偏光成分の光の量の比率である。他の望ましい特徴には、偏光器の効率を低下させたり、ビームの配向など、システムに追加の制約を設けたりすることなく、光学投影システムの偏光器の配置に自由度があることである。
【００４２】
別の偏光技術は、導電性格子またはワイヤ・グリッドを使用する。ワイヤ・グリッド偏光器は、長さが幅よりはるかに長い平行な電気導体が等間隔になった平面のアセンブリであり、導電要素間の間隔は、入射光線の最高周波数光成分の波長より短い。この技術は、無線周波数領域、およびスペクトルの赤外線領域まで、長年使用に成功してきた。導体に平行な偏光の波（Ｓ偏光）は反射し、直交偏光の波（Ｐ偏光）はグリッドを透過する。ワイヤ・グリッド偏光器は、主にレーダ、マイクロ波および赤外線の分野で使用される。
【００４３】
ワイヤ・グリッド偏光器技術は、可視波長範囲での幾つかの場合を除き、比較的短い波長には使用されてこなかった。例えば、米国特許第６，２８８，８４０号では、可視スペクトルのワイヤ・グリッド偏光器が開示されている。ワイヤ・グリッド偏光器は、ガラスなどの材料に埋め込まれ、平行で隔置された細長いアレイ状の要素を含み、これが材料の第１層と第２層の間に挟まれている。細長い要素は、要素間に複数のギャップを形成し、これは第１層の屈折率より小さい屈折率を提供する。要素のアレイは、可視スペクトルの電磁波と相互作用して、第１偏光の光を大部分反射し、第２偏光の光を大部分透過するよう構成される。要素は、０．３ミクロン未満の周期、および０．１５ミクロン未満の幅を有する。
【００４４】
ワイヤ・グリッド偏光器を可視スペクトルの偏光に使用する別の場合が、米国特許第５，３８３，０５３号で開示されている。ワイヤ・グリッド偏光器を、仮想画像表示に使用して、従来のビーム・スプリッタより反射および透過効率を改善する。ワイヤ・グリッド偏光器は、軸線上偏光仮想画像表示のビーム分割要素として使用される。グリッド偏光器の消光率は、この用途では問題にならなかった。この用途では、画像が既に偏光され、反射および透過の比較的高い効率のみが問題だったからである。
【００４５】
Ｌｏｐｅｚその他は、Optical Letters (Vol. 23, No.20, pp.1627 - 1629) で発表した論文で、ワイヤ・グリッド技術に似た表面レリーフ格子偏光の使用について説明している。Ｌｏｐｅｚその他は、垂直入射での１／４波長プレート偏光器（位相遅延π／２）として、および４０°の入射角度での偏光ビーム・スプリッタ（ＰＢＳ）としての可視スペクトル（６３２．８ｎｍでのＨｅ－Ｎｅレーザの出力）における格子偏光の使用を説明している。偏光器は、周期が０．３ミクロン、デューティ・サイクルが５０％の１次元表面レリーフ格子である。格子材料は、単層のSiO_2（屈折率１．４５７）が溶融クォーツ基板上で２層のSi_3N_4（屈折率２．２０）に挟まれている。
【００４６】
しかし、ワイヤ・グリッド偏光器技術は、紫外線波長範囲、つまり４００ｎｍの可視光線下限波長より短い範囲では使用を示唆されていない。上述したように、紫外線の偏光器の開発により、リソグラフィ投影システムの解像度を上げることができ、特に浸漬リソグラフィ・システムの場合のように、高いＮＡを有するリソグラフィ投影システムの解像度を上げることができる。
【００４７】
Ｆｅｒｓｔｌその他は、ＳＰＩＥ (Vol. 3879, Sept. 1999, pp.138 - 146) で発表した論文で、偏光要素として「高周波」格子の使用を開示している。機構サイズが６５０ｎｍの照明波長より小さい２進格子が、クォーツ・ガラス内で、微細構造技術により、直接電子ビーム書き込みを連続的なリアクティブ・イオン・エッチングと組み合わせて製造さ

れている。偏光ビーム・スプリッタでは、横方向電気ＴＥ偏光の－１次で約８０％の回折効率が、横方向磁気ＴＭ偏光の０次で９０％の回折効率が獲得された。

【００４８】

波の偏光状態は、２つのパラメータθおよびφによって定義され、ここでθはＴＥおよびＴＭ波長成分の相対的大きさを定義し、φはその相対的位相を定義する。入射波は、以下の式の対で表すことができる。

$A_{TE}=\cos\theta$ および $A_{TM}=e^{j\phi}\sin\theta$

【００４９】

したがって、φ＝０の場合、波は角度θで直線偏光される。円偏光は、θ＝π／４およびφ＝±π／２の場合に獲得される。ＴＥ偏波はθ＝０で表される。ＴＭ波はθ＝π／２で表される。ＴＥおよびＴＭ偏光は、基本的な偏光成分である。

【００５０】

偏光システムおよび偏光レンズに関する詳細へと進む前に、偏光をその用途の文脈で、つまりリソグラフィ・ツールおよび方法の文脈で考えることが賢明である。

【００５１】

図１は、本発明の実施形態によるリソグラフィ投影装置１を概略的に示す。装置１は、放射線の投影ビームＰＢを供給するよう構築され、配置された放射線システムＥｘ、ＩＬを含み、これはこの特定の場合では放射線ソースＬＡも備え、さらに、マスクＭＡ（レチクルなど）を保持するためにマスク・ホルダを設け、投影システムＰＬに対してマスクを正確に位置決めするための第１位置決めデバイスＰＭに接続された第１オブジェクト・テーブル（マスク・テーブル）ＭＴを含む。基板Ｗ（レジスト被覆したシリコン・ウェハなど）を保持する基板ホルダを設け、投影システムＰＬに対して基板を正確に位置決めする第２位置決めデバイスＰＷに接続された第２オブジェクト・テーブル（基板テーブル）ＷＴ。投影システム（「レンズ」）ＰＬ（ミラー・グループなど）は、マスクＭＡの照射部分を基板Ｗの標的部分Ｃ（例えば１つまたは複数のダイを備える）に描像するよう構成され、配置される。

【００５２】

本明細書で示すように、装置は透過性タイプ（つまり透過性マスクを有する）である。しかし、概して例えば屈折タイプ（屈折性マスクを有する）でもよい。あるいは、装置は、上述したようなタイプのプログラマブル・ミラー・アレイのような別種のパターニング・デバイスを使用してもよい。

【００５３】

ソースＬＡ（放電またはレーザで生成するプラズマ・ソースなど）は放射線ビームを生成する。このビームを、直接、または例えばビーム拡張器Ｅｘなどの調整手段を横断した後、照明システム（照明装置）ＩＬに供給する。照明装置ＩＬは、ビームの強度分布の外径および／または内径範囲（一般にそれぞれ外部σおよび内部σと呼ぶ）を設定する調節手段ＡＭを備えてもよい。また、これは概して、集積器ＩＮおよびコンデンサＣＯなどの様々な他のコンポーネントを備える。この方法で、マスクＭＡに衝突するビームＰＢは、その断面に所望の強度分布を有する。

【００５４】

図１に関して、ソースＬＡは、（ソースＬＡが例えば水銀灯の場合によくあるように）リソグラフィ投影装置のハウジング内でよいが、リソグラフィ投影装置から離れていてもよく、これが生成する放射線ビームを（例えば適切な配向ミラーの助けで）装置内に導いてもよい。後者の場合は、往々にして、ソースＬＡがエキシマ・レーザである。本発明は、これらのシナリオ両方を含む。

【００５５】

ビームＰＢはその後、マスク・テーブルＭＴ上に保持されたマスクＭＡと交差する。マスクＭＡを横切ると、ビームＰＢはレンズＰＬを通過し、これはビームＰＢを基板Ｗの標的部分Ｃに集束する。第２位置決めデバイスＰＷおよび干渉計測定手段ＩＦの助けにより、基板テーブルＷＴを、例えばビームＰＢの路の異なる標的部分Ｃに位置決めするよう、

正確に移動させることができる。同様に、第１位置決めデバイスＰＭを使用して、例えばマスク・ライブラリからマスクＭＡを機械的に取り出した後、または走査中に、ビームＰＢの路に対してマスクＭＡを正確に位置決めすることができる。概して、オブジェクト・テーブルＭＴ、ＷＴの動作は、図１には明示的に図示されていない長ストローク・モジュール（粗い位置決め）および短ストローク・モジュール（微細位置決め）の助けにより実現される。しかし、ウェハ・ステッパの場合、（走査ステップ式装置とは異なり）マスク・テーブルＭＴを短ストローク・アクチュエータに接続するだけ、またはこれに固定すればよい。マスクＭＡおよび基板Ｗは、マスク・アライメント・マークM_1、M_2および基板アライメント・マークP_1、P_2を使用して位置決めすることができる。

【００５６】

図示の装置は、２つの異なるモードで使用することができる。ステップ・モードでは、マスク・テーブルＭＴは基本的に静止状態に維持され、マスク像全体を１回で、つまり１つの「フラッシュ」で標的部分Ｃに投影する。次に、ビームＰＢで異なる標的部分Ｃを照射できるよう、基板テーブルＷＴをＸおよび／またはＹ方向にシフトさせる。

【００５７】

走査モードでは、基本的に同じシナリオが当てはまるが、１つの「フラッシュ」で所与の標的部分Ｃを露光しない。代わりに、マスク・テーブルＭＴは速度ｖで所与の方向（いわゆる「走査方向」、例えばＹ方向）に動作可能であり、したがって投影ビームＰＢにマスク像を走査させる。それと同時に基板テーブルＷＴが速度Ｖ＝Ｍｖで同方向または逆方向に同時に移動し、ここでＭはレンズＰＬの倍率（通常はＭ＝１／４または１／５）である。この方法で、解像度を妥協することなく、比較的大きい標的部分Ｃを露光することができる。

【００５８】

現在、投影リソグラフィに使用するレンズは、ＴＥ偏光器を使用しない。これは、直線偏光または円偏光を有する。本発明より前に使用されているリソグラフィ・ツールの偏光状態は、直線、円形または非偏光である。発明者は、解像度を改善し、ＮＡが１より大きい浸漬リソグラフィなどの高いＮＡでの描像を改善できるようにするため、全機構方向でＴＭ偏光の抑制が必要であると判断した。そうしないと、実行可能な描像を破壊するのに十分なほど、コントラストの損失が甚だしくなってしまう。

【００５９】

ＴＭ偏光を解消し、リソグラフィ投影でＴＥ偏光のみを使用するため、発明者は、円対称レンズにラジアル偏光器を使用すると、ＴＭ偏光成分を選択的になくせることを発見した。ラジアル偏光器の製造は、前述したワイヤ・グリッド技術のそれと同様である。これは、レンズ要素上で、またはレンズ要素内に埋め込んだクロムまたは銀、誘電体または多層などのラジアル周期金属線の製造によって達成される。

【００６０】

図２Ａは、本発明によるラジアル偏光器の実施形態の略図である。ラジアル偏光器２０は、半径方向に対称のパターンで配置された周期格子２２を有する。格子の周期は、使用する特定の放射線の波長および他の所望のパラメータに従い選択することができる。この実施形態では、格子は基板２４上に付着し、これはガラスまたは他の材料でよい。格子２２は、例えばアルミ、クロム、銀、金または電磁放射線ビームの波長で導電性の任意の材料でよい。格子は、例えば誘電体、または例えば単層のSiO_2を溶融クォーツ基板上で２層のSi_3N_4で挟むなど、多層構造の組合せで作成することもできる。格子２２は、例えばＧａＡｓの基板に転写したパターンの後に、電子ビームを使用してエッチングしてもよい。

【００６１】

図２Ｂは、偏光器２０の区域２６における格子２２の拡大図である。図２Ｂで示すように、格子２２は、偏光器の直径に沿ってＴＥ偏光強度の均一性を維持するため、偏光効果が滑らかに遷移できるよう組み合わせてある。

【００６２】

偏光器２２は、図２Ａでは円盤形を有するよう図示されているが、偏光器２０は、長方形、六角形など、多角形でもよい。

【００６３】

図３は、ラジアル偏光器の別の実施形態の拡大側面図である。ラジアル偏光器３０は、第１屈折率を有する材料の第１層３２、第２屈折率を有する材料の第２層３４を含む。方位角で周期的に隔置された複数の細長い要素３６（または格子）を、第１層３２と第２層３４との間に配置する。複数の細長い要素３６が、光または放射線の電磁波と相互作用し、横方向電気ＴＥ偏光は透過させ、ＴＭ偏光は反射するか、吸収する。複数の細長い要素３６は、例えば二酸化シリコンなどで作成することができ、第１および／または第２層３２および／または３４は、例えばクォーツ、シリコン、二酸化物、窒化シリコン、ガリウム砒素などを備える任意の材料、または電磁放射線ビームの波長で誘電体になる材料で作成することができる。以前の実施形態と同様に、細長い要素３６間の間隔または周期は、偏光器の所期の使用、つまり特定の波長に合わせ、リソグラフィ・システムの他のパラメータに従って選択することができる。

【００６４】

同様に、偏光器３０は図３では円盤形の一部か、円盤形を有するよう図示されているが、偏光器３０は、長方形、六角形など、多角形の一部か、多角形を有してもよい。

【００６５】

ほぼ直角の入射角度で偏光器２０、３０に衝突する光は、その偏光状態が変化し、したがって透過偏光状態の出力は、偏光器２０、３０の格子線２２、３６の方向に直角である。

【００６６】

図４は、ＴＥ偏光器２０からの優先的な偏光方向４１および出力を有するベクトル図４０である。ひとみの縁ではＮＡが高いシステムでのＴＥ偏光に対する要求が大きくなるので、偏光器の中心に向かって、誤差および欠陥を大きくすることができる。高密度の線（レチクル像の線）を通って照明するコヒーレント光は、３次の回折を生成する。４２は、光線の０次回折の位置になり、４４および４５では、垂直線のそれぞれ＋１次回折および－１次回折の位置となる。４６および４７は、水平線のそれぞれ＋１次回折および－１次回折の位置となる。＋１および－１次は、ウェハに到達する照明に谷とピークを生成する干渉である。ＴＥ偏光を使用する場合、垂直線と水平線の両方で、干渉パターンが発生して、高いコントラストを、したがって線の良好な解像度を生じる。

【００６７】

直線偏光の場合では、垂直線または水平線のうち一方のみが、高いコントラストで明瞭な干渉パターンになる。他方の垂直または水平線は正しく偏光されず、干渉パターンを形成せずに、コントラストが低くなる。高いコントラストと低いコントラストの像を組み合わせると、結果が平均され、パターン全体で描像の鮮明度または解像度が低下する。ウェハでの干渉がなくなる、または微小になるコンポーネントを回避するため、発明者は、レンズの任意の方位角方向で干渉パターンが生じることができるラジアルＴＥ偏光器を使用した。これは、円偏光には当てはまらない。というのは各コンポーネントが２つの直線直交偏光の組合せであるが、空間中で回転するが、位置の関数として固定した状態であると考えられるからである。したがって、円偏光を使用すると、干渉線が生じず、その結果、リソグラフィ・システムの高解像度描像には適切でない。というのは、ウェハ面で円偏光が直線偏光に変化し、この欠点が本パラグラフ内で上述されているからである。

【００６８】

浸漬リソグラフィ・システム、つまりＮＡが高いリソグラフィ・システムでは、高密度の線を描像するのに十分な解像度を獲得するため、ＴＥ偏光器の使用が必要になることがある。図５は、５０ｎｍの高密度の線を描像する比較用の例１の非偏光浸漬リソグラフィ・システムのプロセス・ウィンドウを示す。この例の使用波長は１９３ｎｍである。使用する浸漬液は、屈折率が１．４３７の水（ＮＡ＝１．４３７）である。空気と等価の開口数ＮＡは１．２９である。この例で使用するレジストは、日本のSumitomo Corp.が作成し

たＰＡＲ７１０で、マッチした基板に載せる。照明は、σ＝０．９／０．７の環状である。図５は、比較用の例１の露光寛容度と焦点深度とのプロットである。このプロットは、０．００の焦点深度における露光寛容度が約５．６％であることを示し、これは使用不可能なレベルである。他の焦点深度では、露光寛容度がさらに低下し、このため非偏光光をＮＡが高いリソグラフィ・システムには使用できなくなる。

【００６９】

図６は、本発明の例１によるＴＥ偏光および浸漬光学系での５０ｎｍの高密度線のプロセス・ウィンドウを示す。この例で使用する波長は１９３ｎｍである。使用する浸漬液は、屈折率が１．４３７の水（ＮＡ＝１．４３７）である。使用レジストは、この例ではマッチした基板上のＰａｒ７１０である。照明は、σ＝０．９／０．７の環状である。図６は、露光寛容度量と焦点深度とのプロットである。このプロットは、０．０の焦点深度における露光寛容度が約９．９％であることを示し、これは使用可能なレベルである。本発明の例１のＴＥラジアル偏光システムを使用すると、比較用の例１と比較して７５％の露光寛容度の改善が得られた。本発明の例１では、比較用の例１と比較して、２７％のＤＯＦの改善が獲得される。したがって、本発明のＴＥ偏光器を使用することにより、プロセス・ウィンドウの向上が可能になる。他の焦点深度では、露光寛容度は焦点深度の増加とともに減少する。

【００７０】

図７は、本発明によるラジアル偏光器の別の実施形態の略図である。ラジアルＴＥ偏光器７０は、複数のプレート偏光器で構成される。ラジアル偏光器７０は、直線偏光が優先されるプレート偏光器７２を切断することによって作成する。プレート偏光器を、円形部片の偏光器を作成するため、プレート・セクタ７２ａ〜ｈに切断する。次に、プレート・セクタ７２ａ〜ｈを組み立てて、ラジアル偏光器７０を形成する。各プレート・セクタ７２ａ〜ｈは、直線偏光ベクトル状態７４ａ〜ｈを有し、したがってこの方法でプレート・セクタ７２ａ〜ｈを集めることにより、直線ベクトル偏光７４ａ〜ｈが回転し、ラジアル偏光形状を形成する。しかし、プレート・セクタは離散的要素であるので、「連続的」ＴＥラジアル偏光を獲得するため、偏光器７０を回転して、プレート間の光路の差をランダム化し、均一性を保証することが好ましい。偏光器の回転は必要ではないが、場合によっては、これが均一性を加え、回転の実現方法に応じて、非常に低速または非常に高速になるよう回転速度を選択することができる。このような回転を実行するために、偏光器７０を、例えば空気軸受けに装着することができる。リソグラフィ・システムの少なくとも部分が真空であるＥＵＶリソグラフィの場合は、代替装着方法を提供することができる。例えば、偏光器７０を、空気軸受けではなく磁気軸受けシステムに装着することができる。回転速度が、偏光の均一性を支配することになる。概して、回転速度は、均一性を保証するため、プレート間の光路の差をランダム化するのに十分高くなければならない。

【００７１】

図８は、本発明のラジアルＴＥ偏光器を使用するリソグラフィ・システムの代替実施形態を概略的に示す。前述したように、リソグラフィ・システム８０は照明または放射線システム・ソース８１、マスクまたはレチクル８２、投影レンズ８２、基板またはウェハ８４およびラジアルＴＥ偏光器２０、３０または７０を備える。ラジアルＴＥ偏光器２０、３０または７０は、この実施形態では、投影レンズの入口に位置するよう図示され、ひとみ面の近傍であることが最適であるが、ラジアル偏光器２０、３０または７０を投影レンズの任意の位置に、または例えばレチクルまたはマスク８２と投影レンズ８３の間など、投影レンズの外側に配置できることが、当業者には理解される。

【００７２】

ラジアル偏光器の最高の性能は、偏光器が完全に導電性の格子（例えばワイヤ・グリッドまたは細長い要素）を有する理想的な偏光器である場合に達成される。この状況で、ラジアル偏光器は、一方の偏光（例えばＴＭ偏光）の光を完全に反射するミラーとして機能し、他方の偏光（例えばＴＥ偏光）の光に対しては完全に透明である。所望の偏光（ＴＥ偏光）が透過し、望ましくない偏光（ＴＭ偏光）は反射される。

【００７３】
しかし、ラジアル偏光器Ｋをレチクル８２と投影レンズ８３との間に配置すると、例えば望ましくない偏光（ＴＭ偏光）を有する反射光はレチクル８２へと戻る。望ましくない偏光を有する反射光は、レチクル８２に衝突し、反射してラジアル偏光器へと戻る。このプロセスで、レチクルで反射した光の一部の偏光が変化することがある。例えばレチクル８２が反射した光の偏光が、少なくとも光の一部がＴＥ偏光（望ましい偏光）に変化したら、ＴＥ偏光（２次光）を有する光のこの部分を、ラジアル偏光器で透過することができる。ラジアル偏光器が、ＴＥ偏光を有する光を通過できるよう構築されているからである。ＴＥ偏光のこの部分は、ラジアル偏光器を最初に透過したＴＥ偏光を有する光（１次ＴＥ偏光）より輝度が低いが、ラジアル偏光器を通過し、最終的に基板８４に到達することができる。この反射現象が多数回繰り返し、ラジアル偏光器との間の路で偏光が変化することができる。これにより、偏光の中にフレアが生成される。２次ＴＥ偏光が、最初にラジアル偏光器を横断したＴＥ偏光（１次ＴＥ偏光）に加えられるからである。偏光フレアは、最終的に描像を不鮮明にし、したがって描像の解像度を低下させる。
【００７４】
描像で偏光フレアが発生する可能性を最低限に抑えるため、発明者は、ラジアル偏光器の導電格子（例えばワイヤ・グリッド）を薄い吸収体の層で被覆すると、偏光器から、およびリソグラフィ装置の他の物体、例えばレチクル８２からの後方反射を削減するのに役立てることができると判断した。
【００７５】
一つの実施形態では、この吸収体層は、図２Ａで示したラジアル偏光器２０の格子２２に任意選択で被覆される。格子２２は、例えばアルミ、クロム、銀、金またはその組合せで作成した導電要素でよい。薄い吸収体の層は、例えば使用する放射線の波長で吸収する材料、例えばAl_2O_3および陽極酸化アルミでよい。薄い吸収体の層は、反射率が低い化合物を含むこともできる。反射率が低い適切な化合物は、ドイツのＺｅｉｓｓのプロセスで作成したＢＩＬＡＴＡＬでよい。他の適切な低反射率化合物には、ＡｌＮおよびCrO_x（ｘは整数）がある。
【００７６】
偏光器の格子２２を薄い吸収体の層で被覆することにより、ラジアル偏光器およびレチクルからの後方反射（２次ＴＥ偏光）は、薄い層で吸収され、１次ＴＥ偏光が薄い吸収体の層に吸収される量は最小限である。これは、後方反射の光（２次ＴＥ偏光）が、１次ＴＥ偏光より低い輝度であり、薄い吸収体の層によって比較的容易に吸収されるからである。吸収体層の厚さおよび／または材料は、後方反射２次ＴＥ偏光の所望の消光率を達成するため、選択または調節することができる。
【００７７】
以上の例示的実施形態では、ラジアル偏光器とレチクル間に発生した後方反射を吸収することについて言及してきたが、上記は反射した偏光の路にある任意のオブジェクトとラジアル偏光器との間で発生するような後方反射の場合にも当てはまることを理解されたい。
【００７８】
吸収媒質をラジアル偏光器と組み合わせて使用することにより、望ましくない偏光を削除する上記のプロセスは、透過性リソグラフィ・ツールを使用する描像用途に有用であり、その例が図１に図示されている。しかし反射性リソグラフィ・ツールの場合は、望ましくない偏光を削除するため、別の構成を使用する。反射性リソグラフィでは、描像に使用するのは反射した偏光である。したがって、吸収するか、削除するのは、透過した望ましくない偏光である。
【００７９】
図９Ａ本発明の一実施形態による吸収体を有する偏光器の略図を示す。偏光器９０は、偏光コンポーネント９２および吸収体９４を含む。吸収体９４は、入射光９６に対して偏光コンポーネント９２の後方に配置される。吸収体９４は、偏光コンポーネント９２の背

面と直接接触するか、偏光器要素９４からわずかに隔置することができる。吸収体９４は、使用する放射線の波長、つまり入射光９６の波長で吸収する材料を含む。入射光９６は、ＴＥ成分の偏光とＴＭ成分の偏光との両方を含む。

【００８０】
前述したように、反射性リソグラフィでは、反射した偏光を描像に使用し、透過した偏光は透過する。この場合、例えばＴＥ偏光成分９７（望ましい偏光）は、偏光コンポーネント９２によって反射し、例えばＴＭ偏光成分９８（望ましくない偏光）は、偏光コンポーネント９２によって透過する。

【００８１】
透過したＴＭ偏光は、その路でオブジェクト、例えばリソグラフィ装置の他の光学描像要素と遭遇することがある。したがって、ＴＭ偏光の一部は、偏光コンポーネント９２へと後方反射することができる。このＴＭ偏光の部分は、偏光コンポーネント９２がＴＭ偏光に対して「透明」であるので、偏光コンポーネント９２を横断する。ＴＭ偏光のこの部分は、ＴＥ偏光（望ましい偏光）より輝度が低いが、望ましいＴＥ偏光に加わり、それと混合して、描像の解像度を劣化させることがある。

【００８２】
リソグラフィ・ツールの他の光学要素から生じる可能性がある後方反射を削減するために、吸収体９４を望ましくないＴＭ偏光９８の光路に導入する。この方法で、ＴＭ偏光は、吸収体９４の厚さｔａに沿って吸収体９４により吸収され、ＴＭ偏光を反射するようなリソグラフィ装置のオブジェクトには到達しない。また、ＴＭ偏光が吸収体９４の厚さｔａを通して光の第１通路で完全に消去されなくても、吸収体９４の底面９４Ｂで反射するＴＭ偏光９９の残りの部分は、吸収体９４の厚さｔａを通してその第２通路で吸収することができる。したがって、望ましくないＴＭ偏光は、吸収体９４によって２回吸収され、ＴＭ偏光成分の直交吸収／消光をもたらす。これによって、ＴＭ偏光成分の消光を強化することができる。吸収体の厚さｔａおよび／または材料は、後方反射２次ＴＥ偏光の望ましい消光を達成するよう選択または調節することができる。

【００８３】
代替実施形態では、偏光コンポーネント９２は、吸収体９４ではなく透過性基板の頂部に配置することができる。偏光コンポーネント９２を透過性基板の頂部に配置した場合は、１／４波長プレートを基板の背後に配置して、望ましくないＴＭ偏光を吸収する。いずれの実施形態でも、ＴＭ偏光成分の消光は、吸収体を組み込むことによって達成され、これは吸収性材料または１／４波長プレートである。さらに、１／４波長プレートを偏光コンポーネント９２と吸収体９４の間に配置してもよい。この場合、望ましくないＴＭ偏光が１／４波長プレートに遭遇し、１／４波長プレートを通過することによって円偏光になる。この円偏光の大部分は、吸収体９４によって吸収される。しかし、吸収体９４の表面で後方反射する光がある場合、この反射光は１／４波長プレートに送られ、再び円形に偏光され、したがってＴＥ偏光に変化する。偏光コンポーネント９２はＴＥ偏光を反射するので、１／４波長プレートを２回通過する光は、偏光コンポーネント９２によって反射し、吸収体９４に送られる。この方法で、この反射光は吸収体９４によって２回吸収される。これは、望ましくない偏光成分、つまりＴＭ偏光の削除または消光を向上させる。

【００８４】
図９Ａに示す偏光コンポーネント９２は、図９Ｂで概略的に示すような格子偏光器９２Ａの構造、または図９Ｃで概略的に示すようなリング偏光器９２Ｂの構造を有することができる。格子偏光器９２Ａは、図２Ａで示すラジアル偏光器２０と同様でよい。格子偏光器９２Ａは、方位角で隔置された半径方向対称のパターンで配置された周期格子９３を有する。図９Ｂの実線の矢印は、ＴＥ偏光成分の形状／方向を示し、点線の矢印はＴＭ偏光成分の形状／方向を示す。前述したように、格子（格子線または細長い要素）に対して直角の方向を有する成分偏光は透過し、格子線に平行な偏光成分は反射する。したがって、格子偏光器９２Ａは、ＴＭ偏光が反射し、ＴＥ偏光が透過するような偏光器である。ＴＥ偏光は、最終的に吸収体９４（図９Ａで図示）によって吸収される。この場合、描像に使

用する成分はＴＭ偏光成分である。しかし、吸収要素９２のこの形状は、反射性リソグラフィでは滅多に使用されない。

【００８５】

これに対して、図９Ｃに示したリング偏光器９２Ｂの構成は、反射性リソグラフィで最も使用される。リング偏光器９２Ｂはリング９５を有し、これは上記で検討したように、吸収体９４（図９Ａに図示）上に配置するか、透過性基板上に配置することができる。リング９５は、同心円上に配置され、周期的に隔置される。図９Ｃの実線の矢印は、ＴＥ偏光成分の形状／方向を示し。点線はＴＭ偏光成分の形状／方向を示す。前述したように、格子に直角、つまりリングの接線に対して直角の方向を有する成分偏光は透過し、リングに正接する偏光成分は反射する。この場合、ＴＭ偏光が透過し、ＴＥ偏光が反射する。ＴＭ偏光は、最終的に吸収体９４（図９Ａで図示）によって吸収される。この場合、描像に使用する成分はＴＥ偏光成分である。

【００８６】

図１０を参照すると、本発明によるデバイス製造方法は、少なくとも部分的に放射線感受性材料の層で覆われた基板を設けることＳ１１０と、放射線システムを使用して投影放射線ビームを設けることＳ１２０と、投影ビームの断面にパターンを与えるため、パターニング・デバイスを使用することＳ１３０と、パターン形成した放射線ビームを、放射線感受性材料の層の標的部分に投影することＳ１４０と、横方向電気偏光で放射線ビームを偏光することＳ１５０とを含む。

【００８７】

図１１は、接線偏光を生成するために使用する本発明による偏光器１００の別の実施形態の略図である。従来の偏光システムは、ビーム分割キューブなどの偏光ユニットを使用することが知られている。ビーム分割キューブは、波面の歪みを最小にするために慎重に貼り合わせた1対の溶融シリカ精密直角プリズムで構成される。プリズムの一方の斜辺は、特定の波長に合わせて最適化された多層偏光ビーム・スプリッタ・コーティング（複屈折材料など）で被覆する。ビーム・スプリッタは、ある量の入射光を捨て、２本のブランチの一方にてキューブの出口で光が直線偏光される。従来は、水平線と垂直線の印刷の差を防止するため、偏光は描像システムのひとみにある１／４波長プレートで円形になる。

【００８８】

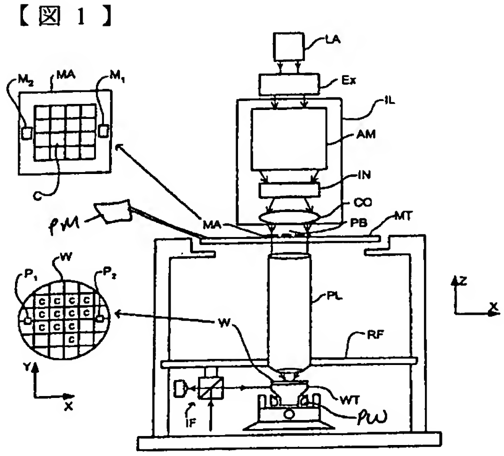
しかし前述したように、円偏光は、両方の基本的偏光成分ＴＥおよびＴＭで構成される。本発明によると、偏光器プレート１０２を、キューブ・ビーム・スプリッタ１０３を備える描像システムのひとみに導入する。一実施形態では、プレート偏光器１０２は２つの１／２波長プレート１０４Ａおよび１０４Ｂを備える。プレート偏光器１０２は直線偏光を偏光して、第１ｓ偏光Ｓ１および第２ｓ偏光Ｓ２にし、したがって第１ｓ偏光の波ベクトルＳ１および第２偏光の波ベクトルＳ２は、相互に対して直角である。プレート偏光器は、キューブ・ビーム・スプリッタ１０３の端部に配置され、したがって一方の偏光方向が、ひとみの２つの１／４部分にのみ制限される。これは、水平線の印刷には適切でない。偏光がｓ偏光としてウェハに到達するからである。他の２つの１／４区分では、複屈折を通して１／２波長位相ずれを導入する（４５°未満）。サジタル（sagital）である偏光は、９０°回転し、接線にもなる。これは、垂直線の印刷に適切である。つまり、第1ｓ偏光Ｓ１を使用して、水平方向でウェハ上に線を印刷し、第２ｓ偏光Ｓ２を使用して、垂直方向でウェハ上に線を印刷する。この方法で、Ｓ偏光またはＴＥ偏光を、垂直線と水平線の両方について獲得する。

【００８９】

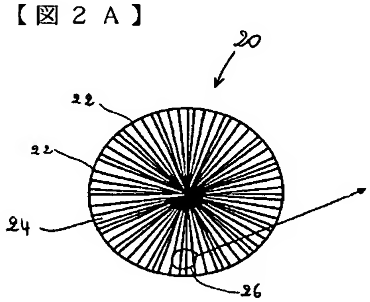
さらに、当業者には多数の変形および変更が容易に思い浮かぶので、本明細書で説明した正確な構造および動作に本発明を制限することは望ましくない。さらに、本発明のプロセス、方法および装置は、リソグラフィ技術で使用する関連の装置およびプロセスと同様に、性質が複雑になる傾向があり、運転パラメータの適切な値を経験的に決定するか、任意の用途にとって最高の設計に到達するため、コンピュータ・シミュレーションを実行することにより、最適に実践されることが多い。したがって、全ての適切な変形および等価

物は、本発明の精神および範囲に入るものと見なされる。
【図面の簡単な説明】
【００９０】
【図１】本発明の実施形態によるリソグラフィ投影装置を概略的に示す。
【図２Ａ】本発明の実施形態によるラジアル偏光器の略図である。
【図２Ｂ】図２Ａで示した偏光器の区域における格子の拡大図である。
【図３】本発明の別の実施形態によるラジアル偏光器の拡大側面図である。
【図４】図２Ａおよび図３で示した実施形態によるＴＥ偏光器からの出力および好ましい偏光方向を示すベクトル図である。
【図５】比較用の例１の露光寛容度と焦点深度とのプロットである。
【図６】本発明の例１の露光寛容度と焦点深度とのプロットである。
【図７】本発明の代替実施形態によるラジアル偏光器の略図である。
【図８】本発明のラジアルＴＥ偏光器を使用するリソグラフィ・システムの実施形態を概略的に示す。
【図９Ａ】本発明の別の実施形態による偏光コンポーネントおよび吸収体を有する横方向偏光器の略図を示す。
【図９Ｂ】図９Ａの偏光器で使用する偏光コンポーネントの実施形態の略図を示す。
【図９Ｃ】図９Ａの偏光器に使用する偏光コンポーネントの別の実施形態の略図を示す。
【図１０】本発明によるデバイス製造方法を表す流れ図である。
【図１１】本発明による偏光器の別の実施形態の略図である。

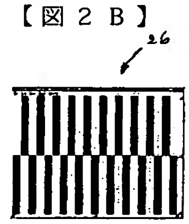
【図１】



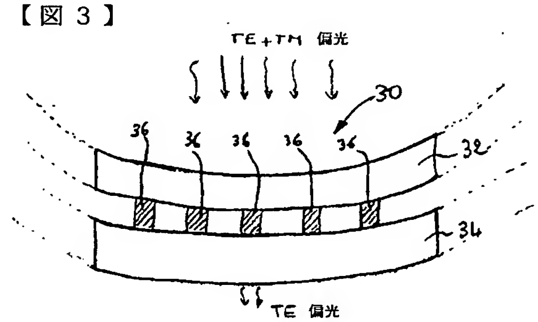
【図２Ａ】



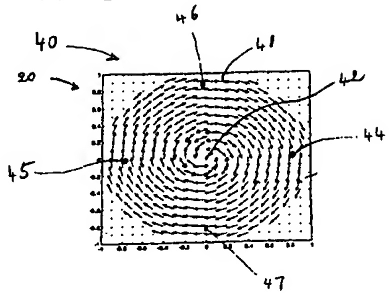
【図２Ｂ】



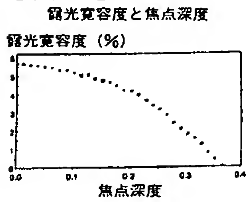
【図３】



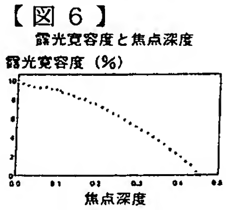
【図４】



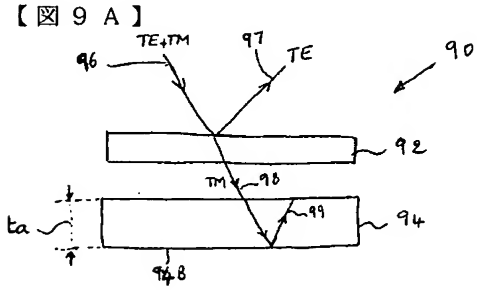
【図５】



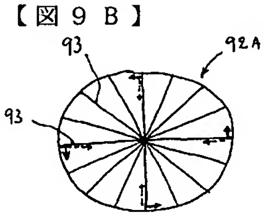
【図６】



【図９Ａ】



【図９Ｂ】



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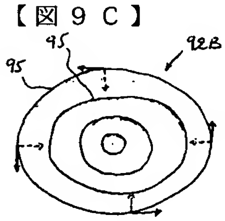

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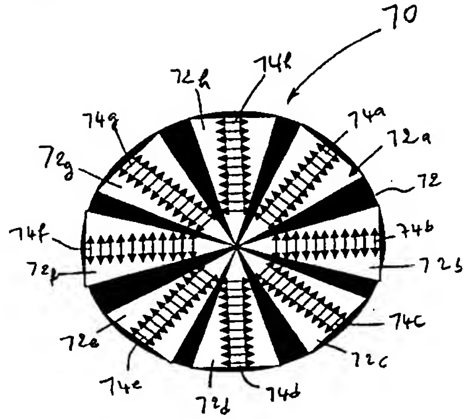

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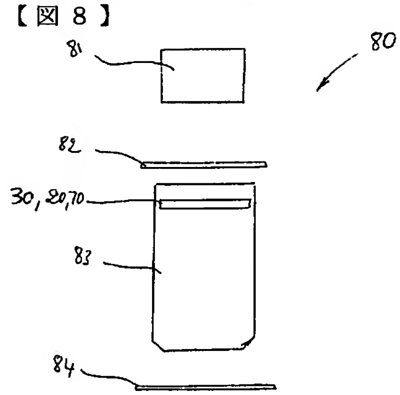

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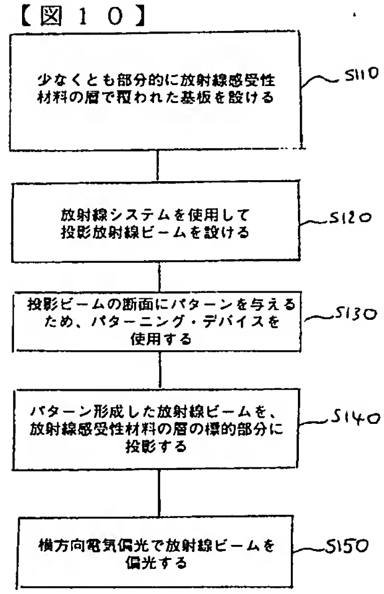

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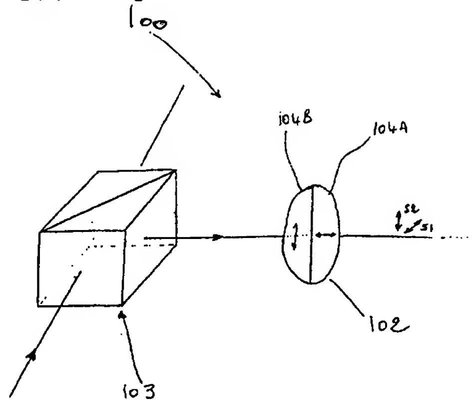

フロントページの続き

(72)発明者　ドニス　ジョージ　フラジェロ
アメリカ合衆国、アリゾナ、スコッツデイル、　イー、ジュアン　タボ　ロード　８１１８
(72)発明者　ケヴィン　カミングス
アメリカ合衆国、アリゾナ、フェニックス、　イー、サピウム　ウェイ　２４１２
(72)発明者　アレクサンダー　シュトラーイヤー
オランダ国、エインドホーフェン、シクラメンストラート　２
(72)発明者　マルセル　マチユス　セオドア　マリー　ディーリヒス
オランダ国、ヴェンロ、シリュルジユンストラート　１

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【外国語明細書】

STATIONARY AND DYNAMIC RADIAL TRANSVERSE ELECTRIC POLARIZER FOR HIGH NUMERICAL APERTURE SYSTEMS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to optical polarizers in general, and more particularly, to polarizers for high numerical aperture lithography.

2. Background of the Invention

[0002] A lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, a patterning device generates a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation sensitive material (resist). In general, a single wafer or substrate will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time.

[0003] The term "patterning device" as here employed should be broadly interpreted as referring to device that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate. The term "light valve" can also be used in this context. Generally, the pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device.

[0004] An example of such a patterning device is a mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase shift, and attenuated phase shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will

generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.

[0005] Another example of a patterning device is a programmable mirror array. One example of such an array is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that, for example, addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind. In this manner, the beam becomes patterned according to the addressing pattern of the matrix addressable surface.

[0006] An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuators. Once again, the mirrors are matrix addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors. In this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronics. In both of the situations described hereabove, the patterning device can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be seen, for example, from United States Patents U.S. 5,296,891 and 5,523,193, and PCT publications WO 98/38597 and WO 98/33096. In the case of a programmable mirror array, the support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

[0007] Another example of a patterning device is a programmable LCD array. An example of such a construction is given in U. S. Patent 5,229,872. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

[0008] For purposes of simplicity, the rest of this text may, at certain locations, specifically

direct itself to examples involving a mask and mask table. However, the general principles discussed in such instances should be seen in the broader context of the patterning device as hereabove set forth.

[0009] In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion at once. Such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus, commonly referred to as a step and scan apparatus, each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction. Since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be seen, for example, from U.S. Patent 6,046,792.

[0010] In a known manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation sensitive material (resist). Prior to this imaging, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement and/or inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemical, mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer and the overlay (juxtaposition) of the various stacked layers is performed as accurate as possible. For this purpose, a small reference mark is provided at one or more positions on the wafer, thus defining the origin of a coordinate system on the wafer. Using optical and electronic devices in combination with the substrate holder positioning device (referred to hereinafter

as "alignment system"), this mark can then be relocated each time a new layer has to be juxtaposed on an existing layer, and can be used as an alignment reference. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

[0011] For the sake of simplicity, the projection system may hereinafter be referred to as the "lens." However, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens." Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in U.S. Patent 5,969,441 and 6,262,796.

[0012] Development of new tools and methods in lithography have lead to improvements in resolution of the imaged features patterned on a device, e.g. an IC. Tools and techniques in optical lithography continue to improve possibly leading to a resolution of less than 50 nm. This may be accomplished using relatively high numerical aperture (NA) lenses (greater than 0.75 NA), wavelengths down to 157 nm, and a plethora of techniques such as phase shift masks, non-conventional illumination and advanced photoresist processes.

[0013] The success of manufacturing processes at these sub-wavelength resolutions will rely on the ability to print low modulation images or the ability to increase the image modulation to a level that will give acceptable lithographic yield.

[0014] Typically, the industry has used the Rayleigh criterion to evaluate the resolution and depth of focus capability of a process. The resolution and depth of focus (DOF) are given by the following equations:

$$\text{Resolution} = k_1 \, (\lambda / NA),$$

and

$$\text{DOF} = k_2 \, (\lambda / NA^2),$$

where λ is the wavelength of the illumination source and k_1 and k_2 are constants for a specific lithographic process.

[0015] Therefore, for a specific wavelength, as resolution is increased through the use of higher-NA tools, the depth of focus can decrease. The loss in DOF with high NA is well known. However, the polarization targets for high NA partially coherent systems have not been examined. According to the following equation:

$$I\,(r, Z_0) = \sum_i \int_s d\rho \, J(\rho_0) \; \Big| \; FT \, \{ O(\rho-\rho_0) \, P_i(\rho) \, F_i(\rho,z) \, H(\rho,Z_0)$$

[0016] where the image I, in a given film such as a photoresist, is a function of position r and specific for a given focus position Z_0. This equation is valid for all NAs and the image is the summation over all polarization states i. The integral is over the source distribution defined by J. The Fourier term within brackets represents the electric field distribution at the exit pupil. The four terms inside the bracket are, respectively, the object spectrum O of the reticle pattern, a polarization function P, a film function F and a pupil function H.

[0017] According to this equation, high NA imaging is intrinsically linked with the polarization state and the thin film structure, where the electric field coupling and the power absorbed by a photoresist film can be drastically altered. The power absorbed due to incident plane waves on a photoresist film are proportional to the exposure necessary to develop the film.

[0018] Studies by Donis G. Flagello et al. published under the title "Optical Lithography

into the Millennium: Sensitivity to Aberrations, Vibrations and Polarization," in the 25th Annual International Symposium on Microlithography, SPIE, February 27-March 3, 2002, Santa Clara, CA, USA, have shown that two orthogonal polarization (Transverse Electric polarization TE and Transverse Magnetic Polarization TM) diverge extensively at high NA, up to a 25% power change. An imaging system would contain a multitude of incident angles, reducing this effect. However, alternating phase shift masks (PSMs) require a small partial coherence which restricts the total number of angles and thus could produce similar exposure changes.

[0019] Results have been obtained through simulation which show that a critical dimension difference from a completely polarized state and the unpolarized state depends on the numerical aperture NA. Results have also shown that dense lines with an alternating phase shift mask (PSM) is the most critical feature and this has been explained by the fact that the pupil configuration essentially produces 2-beam interference at the wafer level and this case tends to maximize the effects of polarization. If, for example, a numerical aperture of 0.85 (relatively high) is selected and one wanted to limit the systematic critical dimension CD error to less than 3%, the residual polarization should be limited to 10%. The critical dimension CD is the smallest width of a line or the smallest space between two lines permitted in the fabrication of a device. The simulation results also indicate the level of pupil filling and partial coherence can lessen the effects of polarization. This has been shown by the small polarization influence on the features using conventional illumination.

[0020] Therefore, as more phase masks are used and imaging technology that demands small coherence levels is used, newer metrology technologies for the lens may be required. For example, high NA polarization effects may result in extremely tight specifications on illumination polarization for lithography tools.

[0021] The advent of a resolution-enhancement technique (RET) called "liquid immersion" promises extending 157 nm optical lithography to well below 70 nm and possibly below 50 nm without changes in illumination sources (lasers) or mask technology. According to a Massachusetts Institute of Technology (MIT) article by M. Switkes et al. entitled "Immersion Lithography at 157 nm" published in J. Vac. Sci. Technology B 19(6),

Nov/Dec 2001, liquid immersion technology could potentially push out the need for next-generation lithography (NGL) technologies such as extreme ultraviolet (EUV) and electron projection lithography (EPL). The liquid immersion technology involves using chemicals and resists to boost resolution. Immersion lithography can enhance the resolution of projection optical systems with numerical apertures up to the refractive index of the immersion fluid. The numerical aperture NA is equal to the product of the index n of the medium and the sinus of the half angle θ of the cone of light converging to a point image at the wafer ($NA = n \sin \theta$). Thus, if NA is increased by increasing the index n, the resolution can be increased (see equation: Resolution = k_1 (λ / NA)). However, as stated above, higher NA may result in extremely tight specifications on illumination polarization for lithography tools. Therefore, polarization plays an increased role in immersion lithography.

SUMMARY OF THE INVENTION

[0022] It is an aspect of the present invention to provide a radial transverse electric polarizer device including a first layer of material having a first refractive index, a second layer of material having a second refractive index, and a plurality of elongated elements azimuthally and periodically spaced apart, and disposed between the first layer and the second layer. The plurality of elongated elements interact with electromagnetic waves of radiation to transmit transverse electric polarization of electromagnetic waves of radiation.

[0023] In one embodiment, the first refractive index is equal to the second refractive index. In another embodiment the plurality of elongated elements form a plurality of gaps. These gaps may include, for example, air or a material having a third refractive index. In yet another embodiment, the elongated elements periodically are spaced apart with a period selected to polarize the electromagnetic waves of radiation in a transverse electric polarization. In one embodiment the electromagnetic radiation is ultraviolet radiation.

[0024] It is another aspect of the present invention to provide a radial transverse electric polarizer device including a substrate material having a first refractive index, and a plurality of elongated azimuthally oriented elements coupled to the substrate material and the elongated elements having a second refractive index. The plurality of elements are

periodically spaced apart to form a plurality of gaps such that the radial transverse electric polarizer device interacts with an electromagnetic radiation having first and second polarizations to reflect substantially all of the radiation of the first polarization and transmit substantially all of the radiation of the second polarization.

[0025] In an embodiment of the present invention the first polarization is a transverse magnetic polarization (TM) and the second polarization is a transverse electric (TE) polarization. The plurality of elongated elements can be formed of, for example, aluminum, chrome, silver and gold. The substrate material can be, for example, quartz, silicon oxide, silicon nitride, gallium arsenide a dielectric material, and combinations thereof.

[0026] In another embodiment of the invention, the radial transverse electric polarizer optionally further includes a thin layer of absorbing material. The plurality of elongated elements are coated with the thin layer of absorbing material which absorbs at a wavelength of the electromagnetic radiation. The thin layer of absorbing material is selected such that a portion of reflected radiation of the first polarization that may have been transformed into a secondary radiation of a second polarization is substantially absorbed by the thin layer of absorbing material. In this way, the thin layer of absorbing material can substantially eliminate polarization flare in the transmitted radiation of the second polarization.

[0027] Another aspect of the invention is to provide a polarizer device including a polarizing component and an absorber disposed on a backside of the polarizing component. The polarizing component interacts with an electromagnetic radiation including first and second polarizations to reflect substantially all radiation of the first polarization and transmit substantially all radiation of the second polarization. The absorber includes a material absorbing at a wavelength of the electromagnetic radiation. The material absorbs substantially all radiation of the second polarization. The polarizer can be used in a reflective-type lithographic apparatus.

[0028] In one embodiment the polarizing component includes a plurality of elongated azimuthally oriented elements. The plurality of elements are periodically spaced apart to form a plurality of gaps. The plurality of elongating elements may be, for example,

electrically conductive at the wavelength of the electromagnetic radiation. In an exemplary embodiment, the first polarization is a transverse magnetic polarization and the second polarization is a transverse electric polarization.

[0029] In another embodiment, the polarizing component includes a plurality of rings disposed concentrically and are periodically spaced. In an exemplary embodiment, the first polarization is a transverse electric polarization and the second polarization is a transverse magnetic polarization.

[0030] According to another aspect of the invention a lithographic projection apparatus is provided, the apparatus including a radiation system constructed and arranged to provide a projection beam of radiation, a support structure constructed and arranged to supporting a patterning device, the patterning device constructed and arranged to pattern the projection beam according to a desired pattern, a substrate table to hold a substrate, a projection system constructed and arranged to project the patterned beam onto a target portion of the substrate, and a polarizer device constructed and arranged to polarize the beam of radiation in a transverse electric polarization direction.

[0031] A further aspect of the invention there is provided a device manufacturing method including projecting a patterned beam of radiation onto a target portion of a layer of radiation-sensitive material at least partly covering a substrate; and polarizing the beam of radiation in a transverse electric polarization. Still another aspect of the invention is to provide a device manufactured a device using the above method.

[0032] Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid crystal display panels, thin film magnetic heads, etc. One will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

[0033] In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV (extreme ultra-violet radiation, e.g. having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] These and other objects and features of the invention will become more apparent and more readily appreciated from the following detailed description of the presently preferred exemplary embodiments of the invention, taken in conjunction with the accompanying drawings, of which:

[0035] Fig. 1 schematically depicts a lithographic projection apparatus according to an embodiment of the invention;

[0036] Fig. 2A is a schematic illustration of a radial polarizer according to an embodiment of the present invention;

[0037] Fig. 2B is an enlarged view of gratings at an area of polarizer depicted in Fig. 2A;

[0038] Fig. 3 is an enlarged lateral view of the radial polarizer according to another embodiment of the present invention;

[0039] Fig. 4 is a vector diagram showing the preferential polarization direction and the output from a TE polarizer according to the embodiments shown in figs. 2A and 3;

[0040] Fig. 5 is a plot of the exposure latitude versus depth of focus for a comparative example 1;

[0041] Fig. 6 is a plot of the exposure latitude versus depth of focus for an example 1 of the present invention;

[0042] Fig. 7 is a schematic illustration of a radial polarizer according to an alternative embodiment of the present invention;

[0043] Fig. 8 shows schematically an embodiment of a lithographic system utilizing the radial TE polarizer of the present invention;

[0044] Fig. 9A shows a schematic illustration of a transverse polarizer having a polarizing component and an absorber according to another embodiment of the present invention;

[0045] Fig. 9B shows a schematic illustration of an embodiment of polarizing component used in the polarizer of Fig. 9A;

[0046] Fig. 9C shows a schematic illustration of another embodiment of a polarizing component used in the polarizer of Fig. 9A;

[0047] Fig. 10 is flow-chart representing a device manufacturing method according to the present invention; and

[0048] Fig. 11 is a schematic illustration of another embodiment of a polarizer according to the present invention.

DETAILED DESCRIPTION

[0049] Several techniques have been used to create polarized light. There are basically four techniques for polarizing a natural beam of light, i.e. non-polarized light. One technique is based on birefringent or biaxial materials. A second technique is based on the use of dichroic materials such as "polaroid." A third technique employs thin-film technology and it uses Brewster's effect. A fourth technique is based on wire grids or conductive gratings.

[0050] The use of birefringent materials to polarize light is known in the production of birefringent polarizers. Birefringent polarizers can be made from many crystals and also certain stretched polymers. Birefringent materials are materials having a different optical index in one direction compared to another. The degree of difference in the optical index

between the two directions varies with the wavelength of the light. The difference in index is used to separate beams of one linear polarization from another. Use of birefringent polarizers is characterized by inefficiency, wavelength dependent performance and requires highly collimated light. For these reasons birefringent polarizers are not commonly used in optical projection systems.

[0051] Dichroic polarizers are polarizers designed to absorb one polarization and transmit the other one. Most commonly used dichroic polarizers consist of a polymeric sheet stretched to orient its molecules and treated with iodine and/or other materials or chemicals such that the molecules absorb polarization of one orientation. Streched polymers polarizers absorb all the intensity of one polarization and at least 15% of the transmitted polarization. Stretched polymer polarizers degrade with time as the light induces chemicals changes in the polymeric material resulting in the material becoming yellow or brittle. Dichroic polarizers are also sensitive to heat and other environmental changes.

[0052] In the last decade a polarizer device has been developed in which stretched polymer sheets are made birefringent. These stretched sheets reflect one polarization and pass the other. One problem with this polarizer technique is its low extinction ratio of approximately 15. While useful for some applications, this extinction ratio is not adequate for imaging applications without a secondary polarizer. This type of polarizer also suffers from the environmental problems discussed above.

[0053] Thin film polarizer technology uses Brewster's effect in which a light beam incident on a surface of a material such as glass, plastic or the like, at Brewster's angle (near 45 degrees) is divided into two polarized beams one transmitted and the other one reflected. Thin film polarizer technology however limits the angular range of the light beam incidence. The acceptance angular range is very narrowly limited to a few degrees in most devices. Thin film polarizer technology also suffers from the wavelength dependence because of the dependence of Brewster's angle on the wavelength of the incident light.

[0054] For an image projection system where applications of a polarized light beam are sought, a brighter beam is always desirable. The brightness of a polarized beam is

determined by numerous factors, one of the factors being the light source itself. Another factor for a system that employs a polarizer is the angle of acceptance. A polarizer with a narrow or limited acceptance angle cannot gather as much light from a divergent source as a system that employs a wide acceptance angle. A polarizer with large acceptance angles allows flexibility in the design of a projection optical system. This is because it is not necessary for the polarizer to be positioned and oriented within a narrow range of acceptance angles with respect to the light source.

[0055] Another desired characteristic for a polarizer is to effectively separate one component of polarization from the other component. This is called the extinction ratio, which is the ratio of the amount of light of the desired polarization component to the amount of light of the undesired polarization component. Other desired characteristics include freedom of positioning the polarizer in an optical projection system without diminishing the efficiency of the polarizer and/or introducing additional restrictions on the system such as orientation of the beam etc.

[0056] Another polarization technique utilizes a conductive grating or wire grid. A wire grid polarizer is a planar assembly of evenly spaced parallel electrical conductors whose length is much larger than their width and the spacing between the conductive elements is less than the wavelength of the highest frequency light component of the incident light beam. This technique has been successfully used for a number of years in the radio frequency domain and up to the infrared region of the spectrum. Waves with a polarization parallel to the conductors (S polarization) are reflected while waves of orthogonal polarization (P polarization) are transmitted through the grid. The wire grid polarizer is used mainly in the field of radar, microwaves, and infrared.

[0057] The wire grid polarizer technique has not been used for shorter wavelengths except in few instances in the visible wavelengths range. For example, in U.S. Patent 6,288,840 a wire grid polarizer for the visible spectrum is disclosed. The wire grid polarizer is imbedded in a material such as glass and includes an array of parallel elongated spaced-apart elements sandwiched between first and second layers of the material. The elongated elements form a plurality of gaps between the elements which provide a refractive index

less than the refractive index of the first layer. The array of elements is configured to interact with electromagnetic waves in the visible spectrum to reflect most of the light of a first polarization and transmit most of the light of a second polarization. The elements have a period less than 0.3 microns and widths less than 0.15 microns.

[0058] Another instance where a wire grid polarizer is used for polarization in the visible spectrum is described in U.S. Patent 5,383,053. A wire grid polarizer is used in a virtual image display to improve reflection and transmission efficiency over conventional beam splitters. The wire grid polarizer is used as a beam splitting element in an on-axis, polarized virtual image display. The extinction ratio of the grid polarizer was not an issue in this application because the image was already polarized and only the relatively high efficiency of the reflection and transmission was of interest in this application.

[0059] Lopez et al., in an article published in Optics Letters, Vol. 23, No. 20, pp. 1627-1629, describe the use of surface-relief grating polarization, similar to wire grid technology. Lopez et al. describe the use of grating polarization in the visible spectrum (output of a He-Ne laser at 632.8 nm) as a quarter-wave plate polarizer (phase retardance, $\pi/2$) at normal incidence and as a polarizing beam splitter (PBS) at an angle of incidence of 40°. The polarizer is a one-dimensional surface-relief grating with a period of 0.3 microns and a 50% duty cycle. The grating material is a single layer of SiO_2 (index of refraction 1.457) sandwiched between two layers of Si_3N_4 (index of refraction 2.20) upon a fused-quartz substrate.

[0060] The wire grid polarizer technology has not been, however, suggested for use in the ultraviolet wavelengths range, i.e. shorter than the visible lower limit wavelength of 400 nm. As stated above, development of a polarizer for ultraviolet radiation would allow increases in resolution of lithographic projection systems, and more specifically increases in the resolution of lithographic projection systems having high NA, such as in the case of immersion lithographic systems.

[0061] Ferstl et al., in an article published in SPIE Vol. 3879, Sept. 1999, pp. 138-146, discloses the use of "high-frequency" gratings as polarization elements. Binary gratings

with feature sizes smaller than the illumination wavelength of 650 nm were fabricated in quartz glass by microstructuring techniques using direct electron-beam writing combined with successive reactive ion etching. In polarization beam splitters diffraction efficiencies of about 80% in the -1 order for transverse electric TE polarization and 90% in the 0 order for transverse magnetic TM polarization were obtained.

[0062] The polarization state of a wave can be defined by two parameters θ and ϕ, where θ defines the relative magnitudes of TE and TM wave components, and ϕ defines their relative phase. The incident wave can be expressed by the following pair of equations:

$$A_{TE} = \cos\theta \text{ and } A_{TM} = e^{j\phi}\sin\theta$$

[0063] Thus, for $\phi = 0$, the wave is linearly polarized at an angle θ. Circular polarization is obtained when $\theta = \pi/4$ and $\phi = \pm\pi/2$. A TE polarized wave is represented by $\theta = 0$. A TM wave is represented by $\theta = \pi/2$. TE and TM polarizations are fundamental polarization components.

[0064] Before going into details about polarization systems and polarization lenses it would be judicious to put the polarization in the context of its application, i.e. in the context of lithographic tools and methods.

[0065] Figure 1 schematically depicts a lithographic projection apparatus 1 according to an embodiment of the invention. The apparatus 1 includes a radiation system Ex, IL constructed and arranged to supply a projection beam PB of radiation (e.g. EUV radiation), which in this particular case also comprises a radiation source LA; a first object table (mask table) MT provided with a mask holder that holds a mask MA (e.g. a reticle), and connected to a first positioning device PM that accurately positions the mask with respect to a projection system PL. A second object table (substrate table) WT provided with a substrate holder that holds a substrate W (e.g. a resist-coated silicon wafer), and connected to a second positioning device PW that accurately positions the substrate with respect to the projection system PL. The projection system ("lens") PL (e.g. a mirror group) is constructed and arranged to image an irradiated portion of the mask MA onto a target

portion C (e.g. comprising one or more dies) of the substrate W.

[0066] As here depicted, the apparatus is of a transmissive type (i.e. has a transmission mask). However, in general, it may also be of a reflective type, for example (with a reflective mask). Alternatively, the apparatus may employ another kind of patterning device, such as a programmable mirror array of a type as referred to above.

[0067] The source LA (e.g. a discharge or laser-produced plasma source) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed a conditioning device, such as a beam expander Ex, for example. The illuminator IL may comprise an adjusting device AM that sets the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

[0068] It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors). This latter scenario is often the case when the source LA is an excimer laser. The present invention encompasses both of these scenarios.

[0069] The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning device PW and interferometer IF, the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning device PM can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke

module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step and scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed. The mask MA and the substrate W may be aligned using mask alignment marks M_1, M_2 and substrate alignment marks P_1, P_2.

[0070] The depicted apparatus can be used in two different modes. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected at once, i.e. a single "flash,"onto a target portion C. The substrate table WT is then shifted in the X and/or Y directions so that a different target portion C can be irradiated by the beam PB.

[0071] In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash." Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g., the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image. Concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

[0072] Currently, lenses that are used in projection lithography do not use TE polarizers. They either have linear polarization or circular polarization. The polarization state in the lithography tools used prior to the present invention are either linear, circular or unpolarized. The inventors have determined that in order to improve resolution and allow better imaging under high NA, such as in immersion lithography where NA is greater than 1, it will require suppression of TM polarization for all feature orientations. Otherwise the loss of contrast would be severe enough to destroy any viable imaging.

[0073] In order to eliminate TM polarization and only use TE polarization in lithographic projection, the inventors have found that using radial polarizers in circularly symmetric lenses allows for selective elimination of the TM polarization component. The manufacture of radial polarizers is similar to that of wire grid technology described

previously. It is accomplished by the manufacture of radial periodic metal lines such as, for example chrome or silver, dielectrics or multilayers, either on a lens element or embedded within the lens element.

[0074] Figure 2A is a schematic illustration of an embodiment of a radial polarizer according to the present invention. Radial polarizer 20 has period gratings 22 arranged in a radially symmetric pattern. The period of the grating can be selected for a specific wavelength of radiation used and in accordance with other desired parameters. In this embodiment, the gratings are deposited on a substrate 24, which can be glass or other materials. The gratings 22 can be, for example, a metal such as aluminum, chrome, silver, gold or any material that is conductive at the wavelength the electromagnetic radiation beam. The gratings can also be made, for example, of dielectrics or a combination in a multilayer structure such as, but not limited to, a single layer of SiO_2 sandwiched between two layers of Si_3N_4 on a fused-quartz substrate. The gratings 22 may also be etched using electron beams, for example, following a pattern transferred to a substrate of GaAs.

[0075] Figure 2B is an enlarged view of gratings 22 at area 26 of polarizer 20. As shown in Figure 2B gratings 22 are interlaced to allow smooth transitions of the polarization effects to maintain uniformity of the TE polarization intensity along the diameter of the polarizer.

[0076] Although the polarizer 22 is illustrated in Figure 2A having a disk shape, the polarizer 20 can also be of a polygonal shape such as, but not limited to, a rectangular shape, hexagonal shape, etc.

[0077] Figure 3 is an enlarged lateral view of another embodiment of the radial polarizer. Radial polarizer 30 includes a first layer of material 32 having a first refractive index, a second layer of material 34 having a second refractive index. A plurality of elongated elements 36 (or gratings) azimuthally and periodically spaced apart are disposed between the first layer 32 and the second layer 34. The plurality of elongated elements 36 interact with electromagnetic waves of light or radiation to transmit transverse electric TE polarization and reflect or absorb TM polarization. The plurality of elongated elements 36

can be made, for example, of silicon dioxide and the first and/or second layers 32 and/or 34 can be made of any material comprising, for example, quartz, silicone, dioxide, silicon nitride, gallium arsenide etc. or a dielectric material at the wavelength of the electromagnetic beam of radiation. Similarly to the previous embodiment the spacing or period between the elongated elements 36 can be selected according to the intended use of the polarizer, i.e. for a specific wavelength and in accordance with other parameters in the lithographic system.

[0078] Similarly, although the polarizer 30 is illustrated in Figure 3 as being part of or having a disk shape, the polarizer 30 can also be part of or having a polygonal shape such as, but not limited to, a rectangular shape, hexagonal shape, etc.

[0079] Light impinging on polarizer 20, 30 at near normal incidence would have its polarization state altered such that the output of transmitted polarization state is orthogonal to the direction of the grating lines 22, 36 in the polarizer 20, 30.

[0080] Figure 4 is a vector diagram 40 with the preferential polarization direction 41 and output from TE polarizer 20. Higher errors and defects would be allowed towards the center of the polarizer as the need for TE polarization with high NA systems is greater at the edge of the pupil. A coherent light illuminating through dense lines (reticle image lines) will produce 3 orders of diffraction. At 42 would be the position of the 0 order diffraction of the beam of light and at 44 and 45, the respective positions of the +1 order diffraction and -1 order diffraction, for a vertical line. At 46 and 47, the respective positions of +1 order diffraction and -1 order of diffraction, for a horizontal line. The +1 and -1 order will interfere giving rise to valleys and peaks in the illumination reaching the wafer. If a TE polarization is used, for both vertical and horizontal lines, an interference pattern occurs leading to a high contrast and thus to a good resolution of the lines.

[0081] Whereas, in the case of linear polarization only one of the vertical or horizontal lines would lead to a clear interference pattern with high contrast. The other vertical or horizontal line would not be correctly polarized, not form an interference pattern and thus the contrast would be less. The combination of high and low contrast images would

average out the result leading to a low definition or resolution imaging for the overall pattern. To get rid of the component leading to absence or minor interference at the wafer the inventors used a radial TE polarizer that allows interference patterns to occur in any azimuthal direction in the lens. This would not be the case with circular polarization as each component is a combination of two linear orthogonal polarizations but can be thought of as turning in space but in a fixed manner as function of position. Therefore, the use of circular polarization would not lead to interference lines and consequently is not suitable for high resolution imaging for lithographic systems because in the wafer plane circular polarization is reduced to linear polarization and the drawbacks of this were described above in this paragraph.

[0082] In an immersion lithographic system, i.e. a lithographic system with a high NA, the use of a TE polarizer may be required in order to obtain the resolution adequate for imaging dense lines. Figure 5 shows the process window for a comparative Example 1 unpolarized immersion lithographic system imaging 50 nm dense lines. The wavelength of use in this example is 193 nm. The immersion fluid used is water with a refractive index of 1.437 (NA=1.437). The air equivalent numerical aperture NA is 1.29. The resist used in this example is PAR710, made by Sumitomo Corp., Japan, on a matched substrate. The illumination is annular with $\sigma = 0.9/0.7$. Figure 5 is a plot of the exposure latitude versus depth of focus for comparative Example 1. This plot indicates that the exposure latitude at a depth of focus of 0.0 is approximately 5.6%, which is an unusable level. At other depth of focus the exposure latitude decreases even more which makes an unpolarized light unusable in lithographic system at high NA.

[0083] Figure 6 shows the process window for a 50 nm dense lines with TE polarized light and immersion optics according to an Example 1 of the present invention. The wavelength of use in this example is 193 nm. The immersion fluid used is water with a refractive index of 1.437 (NA=1.437). The resist used, in this example, is Par710 on a matched substrate. The illumination is annular with $\sigma = 0.9/0.7$. Figure 6 is a plot of the exposure latitude amount versus depth of focus. This plot indicates that the exposure latitude at a depth of focus of 0.0 is approximately 9.9%, which is a usable level. An improvement in exposure latitude of 75% is obtained when using TE radial polarization

system of Example 1 of the present invention compared to comparative Example 1. An improvement in DOF of 27% is obtained in Example 1 of the present invention compared to comparative Example 1. Thus an increased processed window is enabled by the use of the TE polarizer of the present invention. At other depth of focus the exposure latitude decreases with the increase of the depth of focus.

[0084] Figure 7 is a schematic illustration of another embodiment of a radial polarizer according to the present invention. Radial TE polarizer 70 is comprised of a plurality of plate polarizers. Radial polarizer 70 is fabricated by cutting the plate polarizer 72 that have linear polarization preference. The plate polarizers are cut into plate sectors 72a-h in order to fabricate a circular-shaped piece polarizer. The plate sectors 72a-h are then assembled to form a radial polarizer 70. Each plate sector 72a-h has a linear polarization vector state 74a-h and thus by assembling the plate sectors 72a-h in this fashion the linear vector polarization 74a-h would rotate to form radial polarization configuration. However, since the plate sectors are discrete elements, in order to obtain a "continuous" TE radial polarization, polarizer 70 is preferably rotated to randomize optical path differences between the plates and to insure uniformity. The rotation of the polarizer is not necessary but in some cases it would add uniformity and depending on how the rotation is implemented, the speed of the rotation could be selected to be very slow or very fast. To perform such rotation the polarizer 70 can be mounted for example on air bearings. In the case of EUV lithography where at least parts of the lithographic system are in vacuum, an alternative mount solution can be provided. For example, the polarizer 70 can be mounted on magnetic bearing systems instead of air bearings. The speed of rotation would govern the uniformity of the polarization. In general, the rotation rate should be sufficiently high to randomize optical path differences between the plates in order to insure uniformity.

[0085] Figure 8 shows schematically an embodiment of a lithographic system utilizing a radial TE polarizer of the present invention. As described previously, lithographic system 80 comprises illumination or radiation system source 81, mask or reticle 82, projection lens 83, substrate or wafer 84 and a radial TE polarizer 20, 30, or 70. The radial TE polarizer 20, 30, or 70 is shown in this embodiment positioncd at the entrance of the projection lens, optimally close to the pupil plane, however, one ordinary skill in the art would appreciate

that the radial polarizer 20, 30, or 70 can be positioned anywhere in the projection lens or outside the projection lens such as, for example, between the reticle or mask 82 and the projection lens 83.

[0086] A best performance for radial polarizer is achieved when the polarizer is an ideal polarizer having perfectly conducting gratings (for example, wire grids or elongated elements). In this situation, the radial polarizer will function as a perfect mirror totally reflecting light of one polarization (e.g., TM polarization) and will be perfectly transparent for the light with the other polarization (e.g., TE polarization). The desired polarization (TE polarization) will be transmitted while the undesired polarization (TM polarization) will be reflected.

[0087] However, if the radial polarizer is placed between the reticle 82 and the projection lens 83, for example, the reflected light with the undesired polarization (TM polarization) may travel back to the reticle 82. The reflected light with the undesired polarization may impinge on the reticle 82 and be reflected back toward the radial polarizer. In this process, a portion of the light reflected by the reticle may undergo a polarization change. If, for example, the polarization of the light reflected by the reticle 82 has at least a portion of light changed into TE polarization (the desired polarization), this portion of light with TE polarization (secondary light), can be transmitted by the radial polarizer since the radial polarizer is constructed to permit light with TE polarization to pass through. This portion of TE polarized light, albeit less intense than the light with TE polarization that was initially transmitted through the radial polarizer (primary TE polarization light), can pass through the radial polarizer and may eventually reach the substrate 84. This reflection phenomenon may repeat itself numerous times resulting in a change of polarization in a path back and forth to the radial polarizer. This may lead to the creation of a flare in the polarization because secondary TE polarized light is added to the TE polarized light that initially traversed the radial polarizer (primary TE polarized light). The polarization flare can ultimately lead to a blurr in the imaging and thus a loss in imaging resolution.

[0088] In order to minimize the possibility of occurrence of a polarization flare in the imaging, the inventors have determined that coating the conducting gratings (e.g., wire

grids) in the radial polarizer with a thin absorber layer can help reduce back reflections from the polarizer, and from other objects in the lithographic apparatus, for example, the reticle 82.

[0089] In one embodiment, a thin absorber layer is optionally coated on gratings 22 of the radial polarizer 20 illustrated in Figure 2A. The gratings 22 can be conducting elements made from, for example, aluminum, chrome, silver, gold or a combination therefrom. The thin absorber layer can be, for example, any material that is absorbing at the wavelength of radiation used, for example, Al_2O_3 and anodic oxidized aluminum. The thin absorber layer may also contain a compound with low reflection. A suitable compound with low reflection can be BILATAL made by a process from Zeiss, Germany. Other suitable low reflection compounds include AlN and CrO_x (x being an integer number).

[0090] By coating the gratings 22 of polarizer with a thin absorber layer, back reflections (secondary TE polarization) from the radial polarizer and from the reticle, are absorbed by the thin layer while the primary TE polarized light is minimally absorbed by the thin absorber layer. This is because the light of the back reflections (secondary TE polarized light), being less intense than the primary TE polarized light, is relatively easily absorbed by the thin absorber layer. The thickness and or the material of the absorber layer can be selected or adjusted to achieve a desired extinction of the back reflections secondary TE polarized light.

[0091] In the above exemplary embodiment, it has been referred to absorbing back reflections occurring between the radial polarizer and the reticle, however, it should be appreciate that the above also applies in the case of back reflections that may occur between any object in the path of the reflected polarization and the radial polarizer.

[0092] The above process for eliminating undesired polarization by using an absorbing medium in conjunction with a radial polarizer is useful in imaging applications using a transmissive lithographic tool, an example of which is illustrated in Figure 1. In the case of a reflective lithographic tool, however, another configuration is used to eliminate undesired polarization. In reflective lithography, it is the reflected polarization that is used for

imaging. Therefore, it is the transmitted undesired polarization that would be absorbed or eliminated.

[0093] Figure 9A shows a schematic illustration of a polarizer with an absorber according to one embodiment of the invention. Polarizer 90 includes a polarizing component 92 and an absorber 94. Absorber 94 is disposed on the back side of polarizing component 92 relative to incident light 96. Absorber 94 can be disposed directly in contact with a back surface of polarizing component 92 or slightly spaced apart from polarizer element 92. Absorber 94 includes a material that absorbs at the wavelength of radiation used, i.e. at the wavelength of incident light 96. Incident light 96 contains both TE component polarization and TM component polarization.

[0094] As stated previously, in reflective lithography, the reflected polarization is used for imaging while the transmitted polarization is transmitted. In this case, the TE polarization component 97 (desired polarization), for example, is reflected by polarizing component 92 while the TM polarization component 98 (undesired polarization), for example, is transmitted by polarizing component 92.

[0095] The transmitted TM polarization may encounter in its path an object, such as other optical imaging elements in the lithographic apparatus. Hence, a portion of the TM polarized light can be reflected back toward the polarizing component 92. This portion of TM polarized light will traverse the polarizing component 92 because the polarizing component 92 is "transparent" to TM polarization. This portion of TM polarized light, albeit less intense than TE polarization light (desired polarization), can be added to and mixed with the desired TE polarization leading to a deterioration in the imaging resolution.

[0096] In order to eliminate possible back reflections from other optical elements in the lithographic tool, the absorber 94 is introduced in the light path of the undesired TM polarized light 98. In this way, the TM polarized light is absorbed by absorber 94 along the thickness ta of absorber 94 and does not reach an object in the lithographic apparatus that may reflect the TM polarization. In addition, even if the TM polarized light is not totally eliminated in a first passage of the light through thickness ta of absorber 94, the remaining

TM polarized light 99 that may be reflected at the bottom surface 94B of absorber 94 may be absorbed in its second passage through thickness ta of absorber 94. Hence, the undesired TM polarization is absorbed twice by the absorber 94 leading to a quadratic absorption/extinction of the TM polarization component. This allows enhanced extinction of the TM polarization component. The thickness ta and/or the material of the absorber can be selected or adjusted to achieve a desired extinction of the back reflections secondary TE polarized light.

[0097] In an alternative embodiment, the polarizing component 92 may be disposed on top of a transmitting substrate instead of the absorber 94. When the polarizing component 92 is disposed on top of a transmitting substrate, a quarter wave plate is disposed on the back of the substrate to absorb the undesired TM polarization. In either embodiments, the extinction of the TM polarization component is achieved by the incorporation of an absorber, be it an absorbing material or a quarter wave plate. Furthermore, a quarter wave plate may also be disposed between the polarizing component 92 and the absorber 94. In this instance, undesired TM polarization encounters the quarter wave plate and by passing the quarter wave plate becomes circularly polarized. Most of this circularly polarized light will be absorbed by absorber 94. However, if there some light is reflected back by a surface of the absorber 94. This reflected light will be sent towards the quarter wave plate and be polarized again circularly and thus changed into TE polarization. Since the polarizing component 92 reflects TE polarization, the light passing through the quarter wave plate a second time would be reflected by the polarizing component 92 and sent towards the absorber 94. In this way, this reflected light will be absorbed a second time by the absorber 94. This provides an enhanced elimination or extinction of the undesired polarization component, i.e., TM polarization.

[0098] The polarizing component 92 shown in Figure 9A can have a structure of a gratings polarizer 92A as illustrated schematically in Figure 9B or a structure of a ring polarizer 92B as illustrated schematically in Figure 9C. The gratings polarizer 92A may be similar to the radial polarizer 20 shown in Figure 2A. The gratings polarizer 92A has period gratings 93 arranged in a radially symmetric pattern azimuthally spaced apart. The solid arrows in Figure 9B show the configuration/orientation of the TE polarization component

and dotted arrows show the configuration/orientation of the TM polarization component. As stated previously, the component polarization that has an orientation perpendicular to the gratings (grid-lines or elongated elements) are transmitted while the polarization component parallel to the grid-lines is reflected. Thus, the gratings polarizer 92A is such that the TM polarization is reflected and the TE polarization is transmitted. The TE polarization is eventually absorbed by absorber 94 (shown in Figure 9A). In this instance, the component used for imaging is the TM polarization component. This configuration of the absorbing element 92 is, however, rarely used in reflective lithography.

[0099] In contrast, the configuration shown in Figure 9C of a ring polarizer 92B is the most used in reflective lithography. The ring polarizer 92B has rings 95 which can be disposed on absorber 94 (shown in Figure 9A) or disposed on a transmitting substrate as discussed above. The rings 95 are disposed concentrically and are periodically spaced. The solid arrows in Figure 9C show the configuration/orientation of the TE polarization component and the dotted arrows show the configuration/orientation of the TM polarization component. As stated previously, the component polarization that has an orientation perpendicular to the gratings, i.e. perpendicular to a tangent of the rings, are transmitted while the polarization component tangential to the rings is reflected. In this case the TM polarization is transmitted while the TE polarization is reflected. The TM polarization is eventually absorbed by absorber 94 (shown in Figure 9A). In this instance, the component used for imaging is the TE polarization component.

[00100] Referring to Figure 10, a device manufacturing method according to the present invention includes providing a substrate that is at least partially covered by a layer of radiation-sensitive material S110, providing a projection beam of radiation using a radiation system S120, using a patterning device to endow the projection beam with a pattern in its cross-section S130, projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material S140, and polarizing the beam of radiation in a transverse electric polarization S150.

[00101] Figure 11 is a schematic illustration of another embodiment of a polarizer 100 according to the present invention used to create tangential polarization. Conventional

polarization systems are known to use polarization units such as beam-splitting cubes. Beam-splitting cubes consist of a pair of fused silica precision right-angle prisms carefully cemented together to minimize wave front distortion. The hypotenuse of one of the prisms is coated with a multilayer polarizing beam-splitter coating (such as a birefringent material) optimized for a specific wavelength. The beam-splitter throws away an amount of incident light, and at the exit from the cube, in one of the two branches, the light is linearly polarized. Conventionally, in order to prevent differences in printing horizontal and vertical lines, the polarization is rendered circular with a quarter wave plate, in the pupil of the imaging system.

[00102] However as stated previously, circular polarization is comprised of both fundamental polarization components TE and TM. In accordance with the present invention, a polarizer plate 102 is introduced in the pupil of the imaging system comprising the cube beam-splitter 103. In one embodiment, the plate polarizer 102 comprises two half-wave plates 104A and 104B. The plate polarizer 102 polarizes the linear polarized light into a first s-polarized light S1 and a second s-polarized light S2 such that a wave vector S1 of the first s-polarized light and a wave vector S2 of the second polarized light are perpendicular to each other. The plate polarizer is disposed at the end of the cube-beam-splitter 103 such that one polarization direction is limited to only two quarters of the pupil. This is suitable for printing horizontal lines since the polarization arrives as s-polarization on the wafer. In the other two quarters segments, a half-wave phase shift is introduced through birefringence (under 45 degrees). The polarization that was sagital will rotate over 90 degrees and becomes also tangential. This, in turn, is suitable for printing vertical lines. In other words, the first s-polarized light S1 is used to print lines on a wafer in a horizontal direction and the second s-polarized light S2 is used to print lines on a wafer in a vertical direction. In this way, S-polarization or TE polarization is obtained for both vertical and horizontal lines.

[00103] Furthermore, since numerous modifications and changes will readily occur to those of skill in the art, it is not desired to limit the invention to the exact construction and operation described herein. Moreover, the process, method and apparatus of the present invention, like related apparatus and processes used in the lithographic arts tend to be

complex in nature and are often best practiced by empirically determining the appropriate values of the operating parameters or by conducting computer simulations to arrive at a best design for a given application. Accordingly, all suitable modifications and equivalents should be considered as falling within the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A radial transverse electric polarizer device, comprising:
a first layer of material having a first refractive index;
a second layer of material having a second refractive index; and
a plurality of elongated elements azimuthally and periodically spaced apart, and disposed between said first layer and said second layer,
wherein said plurality of elongated elements interact with electromagnetic waves of radiation to transmit transverse electric polarization of electromagnetic waves of radiation.

2. A radial transverse electric polarizer device according to claim 1,
wherein said first refractive index is equal to said second refractive index.

3. A radial transverse electric polarizer device according to claim 1,
wherein said plurality of elongated elements form a plurality of gaps.

4. A radial transverse electric polarizer device according to claim 3,
wherein said gaps include air.

5. A radial transverse electric polarizer device according to claim 3,
wherein said gaps include a material having a third refractive index.

6. A radial transverse electric polarizer device according to claim 1,
wherein said elongated elements have a fourth refractive index.

7. A radial transverse electric polarizer device according to claim 1,
wherein said elongated elements periodically are spaced apart with a period selected to polarize said electromagnetic waves of light in a transverse electric polarization.

8. A radial transverse electric polarizer device according to claim 1,
wherein said electromagnetic radiation is ultraviolet radiation.

9. A radial transverse electric polarizer device, comprising:

a substrate material having a first refractive index; and

a plurality of elongated azimuthally oriented elements coupled to said substrate material, said elongated elements having a second refractive index,

wherein said plurality of elements are periodically spaced apart to form a plurality of gaps such that said radial transverse electric polarizer device interacts with an electromagnetic radiation comprising first and second polarizations to reflect substantially all of the radiation of the first polarization and transmit substantially all of the radiation of the second polarization.

10. A radial transverse electric polarizer device according to claim 9,

wherein said first polarization is a transverse magnetic polarization and said second polarization is a transverse electric polarization.

11. A radial transverse electric polarizer device according to claim 9,

wherein said plurality of elongated elements are formed of an electrically conductive material at a wavelength of said electromagnetic radiation.

12. A radial transverse electric polarizer device according to claim 11,

wherein said electrically conductive material is selected from the group: aluminum, chrome, silver and gold.

13. A radial transverse electric polarizer device according to claim 9,

wherein said substrate material is formed of a dielectric material at a wavelength of said electromagnetic radiation.

14. A radial transverse electric polarizer device according to claim 13,

wherein said dielectric material is selected from the group: quartz, silicon oxide, silicon nitride, gallium arsenide and combinations thereof.

15. A radial transverse electric polarizer device according to claim 9,

wherein said substrate material comprises a dielectric material.

16. A radial transverse electric polarizer device according to claim 9, further comprising:

a thin layer of absorbing material, said thin layer of absorbing material absorbing radiation at a wavelength of said electromagnetic radiation,

wherein said plurality of elongated elements are coated with said thin layer of absorbing material.

17. A radial transverse electric polarizer device according to claim 16,

wherein said thin layer of absorbing material is selected such that a portion of reflected radiation of the first polarization transformed into a secondary radiation of a second polarization is substantially absorbed by said thin layer of absorbing material.

18. A radial transverse electric polarizer device according to claim 17,

wherein the radiation of the second polarization is minimally absorbed by said thin layer of absorbing material.

19. A radial transverse electric polarizer according to claim 18,

wherein said thin layer of absorbing material substantially eliminates polarization flare in the transmitted radiation of a second polarization.

20. A radial transverse electric polarizer device according to claim 9,

wherein the second polarization is a transverse electric polarization.

21. A radial transverse electric polarizer device according to claim 16,

wherein said thin layer of absorbing material is selected from the group: Al_2O_3 and anodic oxidized aluminum.

22. A lithographic projection apparatus, comprising:

a radiation system configured to provide a projection beam of radiation;

a support structure configured to support a patterning device, the patterning device configured to pattern the projection beam according to a desired pattern;

a substrate table configured to hold a substrate;

a projection system configured to project the patterned beam onto a target portion of the substrate; and

a polarizer device constructed and arranged to polarize said beam of a radiation in a transverse electric polarization direction.

23. A lithographic projection apparatus according to claim 22,

wherein said polarizer device comprises:

a first layer of material having a first refractive index;

a second layer of material having a second refractive index; and

a plurality of elongated elements azimuthally and periodically spaced apart, and disposed between said first layer and said second layer,

wherein said plurality of elongated elements interact with said beam of radiation to transmit transverse electric polarization of said beam of radiation.

24. A lithographic projection apparatus according to claim 22,

wherein said polarizer device comprises:

a substrate material having a first refractive index;

a plurality of elongated azimuthally oriented elements coupled to said substrate material, said elongated elements having a second refractive index, and

wherein said plurality of elements are periodically spaced apart to form a plurality of gaps such that said radial transverse electric polarizer device interacts with the beam of radiation comprising first and second polarizations to reflect substantially all of the radiation of the first polarization and transmit substantially all of the radiation of the second polarization.

25. A lithographic projection apparatus according to claim 24,

wherein said polarizer device further comprises a thin layer of absorbing material, said thin layer of absorbing material absorbing radiation at a wavelength of said electromagnetic radiation,

wherein said plurality of elongated elements are coated with said thin layer of absorbing material.

26. A lithographic projection apparatus according to claim 25,
wherein said thin layer of absorbing material is selected such that a portion of reflected radiation of the first polarization transformed into a secondary radiation of a second polarization is substantially absorbed by said thin layer of absorbing material.

27. A lithographic projection apparatus according to claim 26,
wherein the radiation of the second polarization is minimally absorbed by said thin layer of absorbing material.

28. A lithographic projection apparatus according to claim 27,
wherein said thin layer of absorbing material substantially eliminates polarization flare in the transmitted radiation of a second polarization.

29. A lithographic projection apparatus according to claim 25,
wherein the second polarization is a transverse electric polarization.

30. A lithographic projection apparatus according to claim 25,
wherein said thin layer of absorbing material is selected from the group: Al_2O_3 and anodic oxidized aluminum.

31. A lithographic projection apparatus according to claim 22,
wherein a wavelength range of said radiation beam is in the ultraviolet spectrum.

32. A lithographic projection apparatus according to claim 31,
wherein said wavelength range is between 365 nm and 126 nm.

33. A lithographic projection apparatus according to claim 31,
wherein said wavelength range is in the extreme ultraviolet.

34. A radial transverse electric polarizer device which interacts with an electromagnetic radiation comprising first and second polarizations to reflect substantially all of the

radiation of the first polarization and transmit substantially all of the radiation of the second polarization, said polarizer device comprising:

a plurality of sector-shaped linear polarizer plates, each defining a plurality of parallel linear polarization orientations,

wherein said plurality of sector-shaped linear polarizer plates are azimuthally arranged such that said plurality of parallel linear polarization orientations rotate to form a radial polarization configuration.

35. A radial transverse electric polarizer device according to claim 34,

wherein said radial transverse polarizer is constructed and arranged to rotate around an axis perpendicular to a plane defined by said radial transverse polarizer.

36. A device manufacturing method, comprising:

projecting a patterned beam of radiation onto a target portion of a layer of radiation-sensitive material at least partially covering a substrate; and

polarizing said beam of radiation in a transverse electric polarization.

37. A device manufactured according to the method of claim 36.

38. A tangential polarizer device, comprising:

a cube beam-splitter polarizer constructed and arranged to polarize at least a portion of an incident light into a linear polarized light; and

a polarizing plate comprising two half-wave plates,

wherein said polarizing plate is disposed at an end of said cube beam-splitter polarizer to polarize said linear polarized light into a first s-polarized light and a second s-polarized light such that a wave vector of said first s-polarized light and a wave vector of said second s-polarized light are perpendicular to each other.

39. The tangential polarizer device according to claim 38, wherein said first s-polarized light is used to print lines on a wafer in a horizontal direction and said second s-polarized light is used to print lines on a wafer in a vertical direction.

40. A polarizer device comprising:

a polarizing component; and

an absorber disposed on a backside of said polarizing component,

wherein said polarizing component interacts with an electromagnetic radiation comprising first and second polarizations to reflect substantially all radiation of the first polarization and transmit substantially all radiation of the second polarization, and said absorber includes a material absorbing at a wavelength of said electromagnetic radiation, said material absorbing substantially all radiation of said second polarization.

41. A polarizer device according to claim 40,

wherein said polarizing component comprises a plurality of elongated azimuthally oriented elements, said plurality of elements being periodically spaced apart to form a plurality of gaps.

42. A polarizer device according to claim 41,

wherein said plurality of elongated elements are electrically conductive at the wavelength of the electromagnetic radiation.

43. A polarizer device according to claim 40,

wherein said first polarization is a transverse magnetic polarization and said second polarization is a transverse electric polarization.

44. A polarizer device according to claim 40,

wherein said polarizing component comprises a plurality of rings disposed concentrically, said rings being periodically spaced.

45. A polarizer device according to claim 44,

wherein said first polarization is a transverse electric polarization and said second polarization is a transverse magnetic polarization.

46. A reflective-type lithographic apparatus using a polarizer device according to claim 40.

47. A polarizer device according to claim 40, wherein said material absorbing at said wavelength of the electromagnetic radiation is selected from the group: Al_2O_3 and anodic oxidized aluminum.

ABSTRACT

1 Abstract

A radial transverse electric polarizer includes a first layer of material having a first refractive index, a second layer of material having a second refractive index, and a plurality of elongated elements azimuthally and periodically spaced apart, and disposed between the first layer and the second layer. The plurality of elongated elements interact with electromagnetic waves of radiation to transmit transverse electric polarization of electromagnetic waves of radiation. The polarizer device may be used, for example, in a lithographic projection apparatus to increase imaging resolution. A device manufacturing method includes polarizing a beam of radiation in a transverse electric polarization.

2. Representative Drawing

Fig. 1

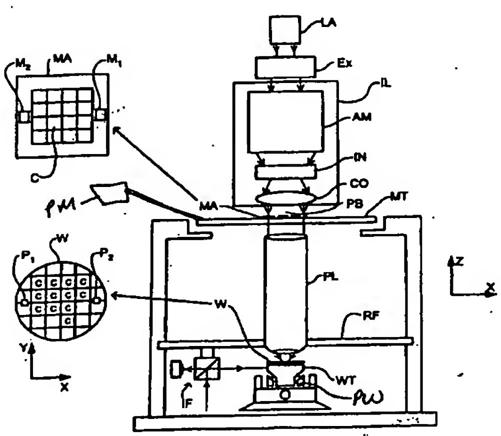

Fig. 1

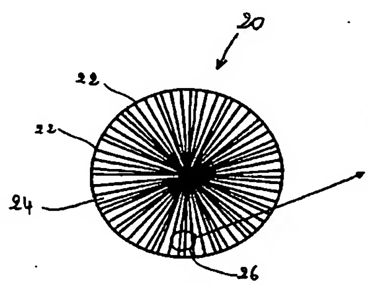

Fig. 2A

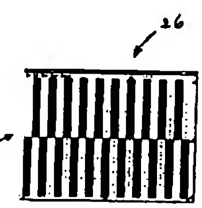

Fig. 2B

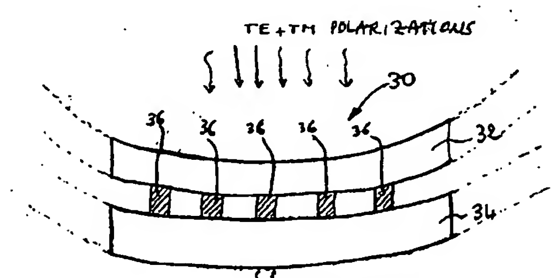

Fig. 3

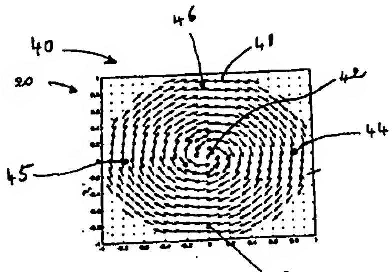

Fig. 4

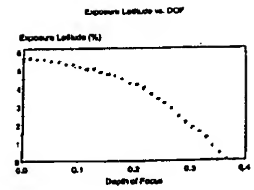

Fig. 5

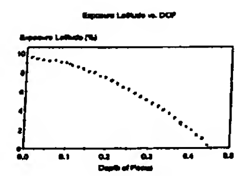

Fig. 6

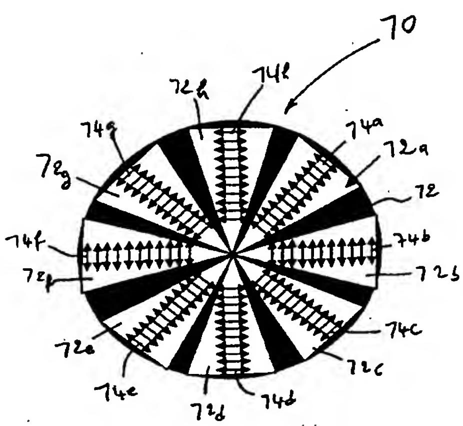

Fig. 7

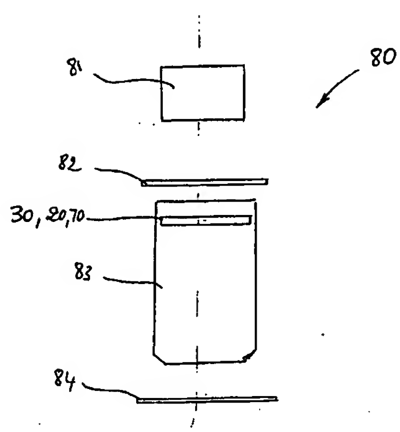

Fig. 8

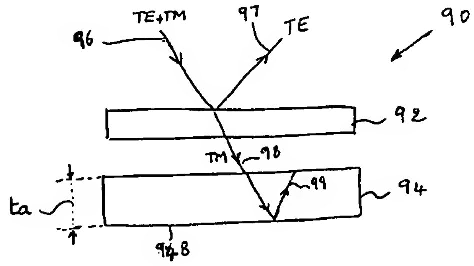

FIG. 9A

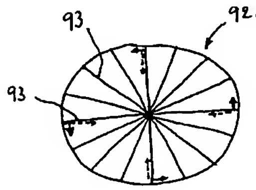

FIG. 9B

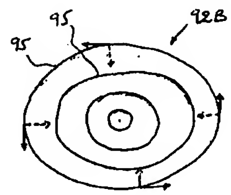

FIG. 9C

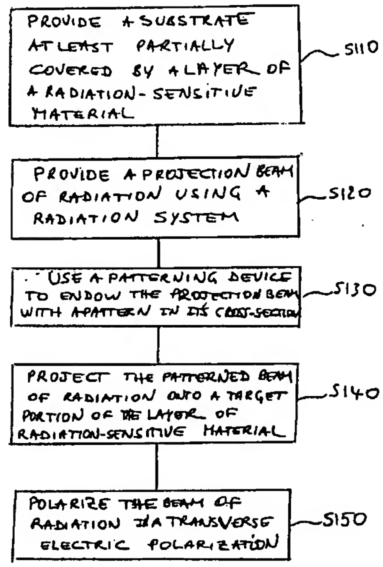

Fig. 10

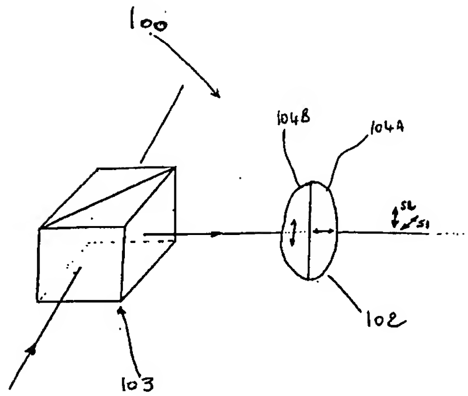

Fig. 11